QUALITY ASSURANCE PROJECT PLAN
LUMMI NATION CONTINUOUS TEMPERATURE MONITORING PROGRAM

Version 1.0

Water Resources Division
Natural Resources Department
Lummi Indian Business Council

September 2015

Lummi Nation Continuous Temperature Monitoring Quality Assurance Project Plan Approval (A1):

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This project has been funded wholly or in part by the United States Environmental Protection Agency under Assistance Agreement BG-00J89601-0 to the Lummi Nation. The contents of this document do not necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

TABLE OF CONTENTS (A2)

1. DISTRIBUTION LIST (A3) 1

2. PROJECT ORGANIZATION (A4) 3

2.1 SPECIAL TRAINING REQUIREMENTS AND CERTIFICATION (A8) 6

3. PROBLEM DEFINITION AND BACKGROUND (A5) 9

3.1 PROGRAM SUMMARY 9
3.2 PROGRAM CONTEXT 9
3.3 PROJECT LOCATION 10
3.4 WATER TEMPERATURE 10
3.5 LUMMI NATION SURFACE WATER QUALITY STANDARDS 11
3.6 PROJECT JUSTIFICATION 13

4. PROJECT DESCRIPTION (A6) AND EXPERIMENTAL DESIGN (B1) 15

4.1 DESIGN JUSTIFICATION 18
4.2 ALTERNATE SITES 20
4.3 PROJECT TIMELINE 22

5. QUALITY OBJECTIVES AND CRITERIA FOR MEASUREMENT DATA (A7) 23

5.1 OBJECTIVES AND PROJECT DECISIONS 23
5.2 MEASUREMENT PERFORMANCE CRITERIA/ACCEPTANCE CRITERIA 24
5.3 PRECISION 24
5.4 ACCURACY AND BIAS 24
5.5 REPRESENTATIVENESS 25
5.6 COMPARABILITY 25
5.7 COMPLETENESS 26
5.8 RANGE/SENSITIVITY 26

6. DOCUMENTS AND RECORDS (A9) 27

6.1 QUALITY ASSURANCE PROJECT PLAN DISTRIBUTION 27
6.2 DOCUMENTATION AND RECORDS 27
6.3 ANNUAL REPORTS 29

7. LOGGER DEPLOYMENT AND DATA COLLECTION (B2 SAMPLING METHODS) 31

7.1 SAFETY 31
7.2 DEPLOYMENT LOCATION 31
7.2.1 Representative Location 31
7.2.2 Cross-Section Survey 32
7.3 LOGGER PREPARATION FOR DEPLOYMENT 33
7.3.1 Protective Housing 33
7.3.2 Pre-Deployment QA/QC 33
7.3.3 Logger Set-Up 33

7.4 DEPLOYMENT STRATEGY 34
7.4.1 Rebar 34
7.4.2 Cable 34
7.4.3 Cinder Block 34
7.4.4 Custom Block 34
7.4.5 Weight and Buoy 34
7.4.6 Air Temperature 35
7.4.7 Canopy Cover 35
7.5 DATA DOWNLOAD 35
7.6 LOGGER DEPLOYMENT AND FIELD ACTIVITY FLOWCHART 35

8. QUALITY ASSURANCE AND QUALITY CONTROL REQUIREMENTS (B5) 39

8.1 LOGGER CALIBRATION 39
8.2 ACCURACY CHECK – PRIOR TO INITIAL DEPLOYMENT 39
8.2.1 Two-Point Accuracy Check Methods 39
8.3 ACCURACY CHECK – FIELD 41
8.3.1 Equipment 41
8.3.2 In the lab: accuracy check of reference temperature probe 41
8.3.3 In the field: sensor error caused by fouling and calibration drift 42
8.3.4 Data correction in the field 44
8.4 ACCURACY CHECK – ANNUAL LAB CHECK 44
8.5 ADDITIONAL ACCURACY CHECKS 44
8.6 ACCEPTANCE CRITERIA AND CORRECTIVE ACTIONS 45
8.7 REQUIREMENTS OF THE REFERENCE THERMOMETER 46
8.8 CORRECTIVE ACTIONS 46
8.9 EQUIPMENT MAINTENANCE (B6) AND CALIBRATION (B7) 47

9. DATA MANAGEMENT (B10) 49

9.1 QA/QC DATA 49
9.2 DATA SCREENING AND IDENTIFICATION OF DATA ERRORS 49
9.3 DATA CORRECTION 51
9.4 SUMMARY STATISTICS 52
9.5 ASSESSMENTS, OVERSIGHT AND RESPONSE ACTIONS (C1) 52
9.6 REPORTS TO MANAGEMENT (C2) 52
9.7 EXTERNAL DATA ACQUISITION (B9) 53
9.8 DATA REVIEW AND USABILITY 53
9.8.1 Data Review, Verification, and Validation Requirements (D1) 53
9.8.2 Verification and Validation Methods (D2) 53
9.8.3 Reconciliation with User Requirements (D3) 54

10. REFERENCES 57

11. ACRONYMS AND ABBREVIATIONS 61

12. APPENDICES 63

Appendix A. Equipment/Instrument Manual for HOBO Water Temp Pro v2 (U22-001) 65
Appendix B. Standard Operating Procedures for HOBO Water Temp Pro v2 (U22-001) 69
Appendix C. Protective Housing for Continuous Temperature Loggers 73
Appendix D. Deployment Technique Schematics 75
Appendix E. Data Sheets for Lab and Field Accuracy Checks 77
Appendix F. Decision Trees 83

LIST OF TABLES

Table 2.1 Lummi Water Resources Division Position Requirements 6
Table 2.2 Training Requirements (Water Resources Specialist and Technician Positions) 7
Table 3.1 Lummi Nation Surface Water Quality Standards Characteristic Uses and Temperature Criteria 12
Table 4.1 Continuous Temperature Monitoring Sites 16
Table 4.2 Rationale of Site Selection for Continuous Temperature Monitoring Program 19
Table 4.3 Estimated Timeline for Task Implementation 22
Table 8.1 Acceptance Criteria and Corrective Actions 45
Table 8.2 Troubleshooting and Corrective Actions for Potential Problems 47
Table 9.1 Data Correction Actions 51
Table 12.1 Range, Accuracy, and Sensitivity/Readability of HOBO Water Temp Pro v2 69
Table 12.2 Battery Life, Memory and Response Time of HOBO Water Temp Pro v2 69
Table 12.3 Issues and Potential Solutions 72

LIST OF FIGURES

Figure 2.1 LNR Key Staff Involved In Continuous Temperature Monitoring Program 5
Figure 4.1 Location of Continuous Temperature Monitoring Sites 17
Figure 4.2 Alternate continuous temperature monitoring sites 21
Figure 7.1 Schematic of temperature measuring points in cross-section stream survey 33
Figure 12.1 Schematic of continuous temperature logger in protective housing 73
Figure 12.2 Schematic for rebar deployment technique 75
Figure 12.3 Schematic of the custom-built concrete block deployment technique 75
Figure 12.4 Schematic of cinder block deployment technique 76
Figure 12.5 Schematic of weight and buoy deployment technique 76
Figure 12.6 Laboratory Accuracy Check Data Sheet for use during two-point accuracy check prior to initial deployment of loggers and during annual laboratory check 78
Figure 12.7 Field Accuracy Check Data Sheet for field reference temperature probe 79
Figure 12.8 Field Accuracy Check Data Sheet for use during field accuracy checks and calculation of sensor error caused by fouling and sensor error caused by calibration drift 80
Figure 12.9 Field Accuracy Check Data Sheet for use during field accuracy checks and calculation of sensor error caused by fouling and sensor error caused by calibration drift 81
Figure 12.10 Stream cross-section survey datasheet for use in determining representativeness of temperature logger deployment location and horizontal and vertical stratification. 82

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1. DISTRIBUTION LIST (A3)

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Recipients identified on this distribution list will be sent updated versions of this document or copies of minor change letters for this document immediately after they are approved. Recipients listed may also obtain the most current copy of the approved Quality Assurance Project Plan (QAPP) by contacting the Water Resources Manager or the Water Resources Specialist I.

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2. PROJECT ORGANIZATION (A4)

The Continuous Temperature Monitoring Program is implemented and administered through the Lummi Water Resources Division (LWRD) of the Lummi Natural Resources Department (LNR). The LWRD Manager directly reports to the Director and Deputy Director of the LNR (Figure 2.1). The Lummi Fisheries and Natural Resources Commission provides policy direction to the Director. The LNR is an administrative division of the Lummi Indian Business Council (LIBC), which is the elected governing body of the Lummi Nation.

The Continuous Temperature Monitoring Program is implemented by a number of key staff members. Table 2.1 identifies these key personnel, provides contact information, identifies their roles and responsibilities with respect to the Continuous Temperature Monitoring Program, and identifies their relative positions, position requirements, and held qualifications.

The Director and Deputy Director are the policy decision makers for the LNR. The Director ensures that the Deputy Director has the resources necessary to fulfill the project oversight responsibilities associated with this project. The Deputy Director in turn ensures that the Water Resources Manager has the resources necessary to fulfill the project management responsibilities associated with this project.

The Water Resources Manager is responsible for administering contracts and overseeing the budget for the Continuous Temperature Monitoring Program. In addition, the Water Resources Manager serves as the Project Manager and Quality Assurance Manager for the Continuous Temperature Monitoring Program. The organization is too small to provide for a completely independent Quality Assurance Manager. The Water Resources Manager supervises, directly or indirectly, the Water Resources Specialist II, Water Resources Specialist I, and the Water Resources Technician III, and evaluates and analyzes the data on an as-needed basis; however, the Water Resources Manager generally does not directly collect water quality data or manage the water quality data collection. The Water Resources Manager makes recommendations to the Director and Deputy Director, who make decisions based upon data collected under the Continuous Temperature Monitoring Program.

The Water Resources Specialist II provides oversight of the Continuous Temperature Monitoring Program, supervises and supports the work of the Water Resources Specialist I (including data collection as needed) and performs regular Quality Assurance audits that the Water Resources Manager evaluates for compliance with the project goals.

The Water Resources Specialist I is the primary staff person responsible for the Continuous Temperature Monitoring Program coordination, implementation, data evaluation and analysis. Duties also include maintaining the official, approved Quality Assurance Project Plan (QAPP), equipment maintenance, supply management, and supervising the work of the Water Resources Technician III. The Water Resources Specialist I and Water Resources Technician III are responsible for implementing the Continuous Temperature Monitoring Program, including logger deployment and maintenance, following quality assurance and quality control (QA/QC) protocols, and data management.

The Natural Resources Specialist I will provide support to the Water Resources Specialist I related to the Continuous Temperature Monitoring Program, including data collection, on an as needed basis.

The Database Manager created and maintains the Continuous Temperature Monitoring Database and is the primary staff member responsible for database training and documentation.

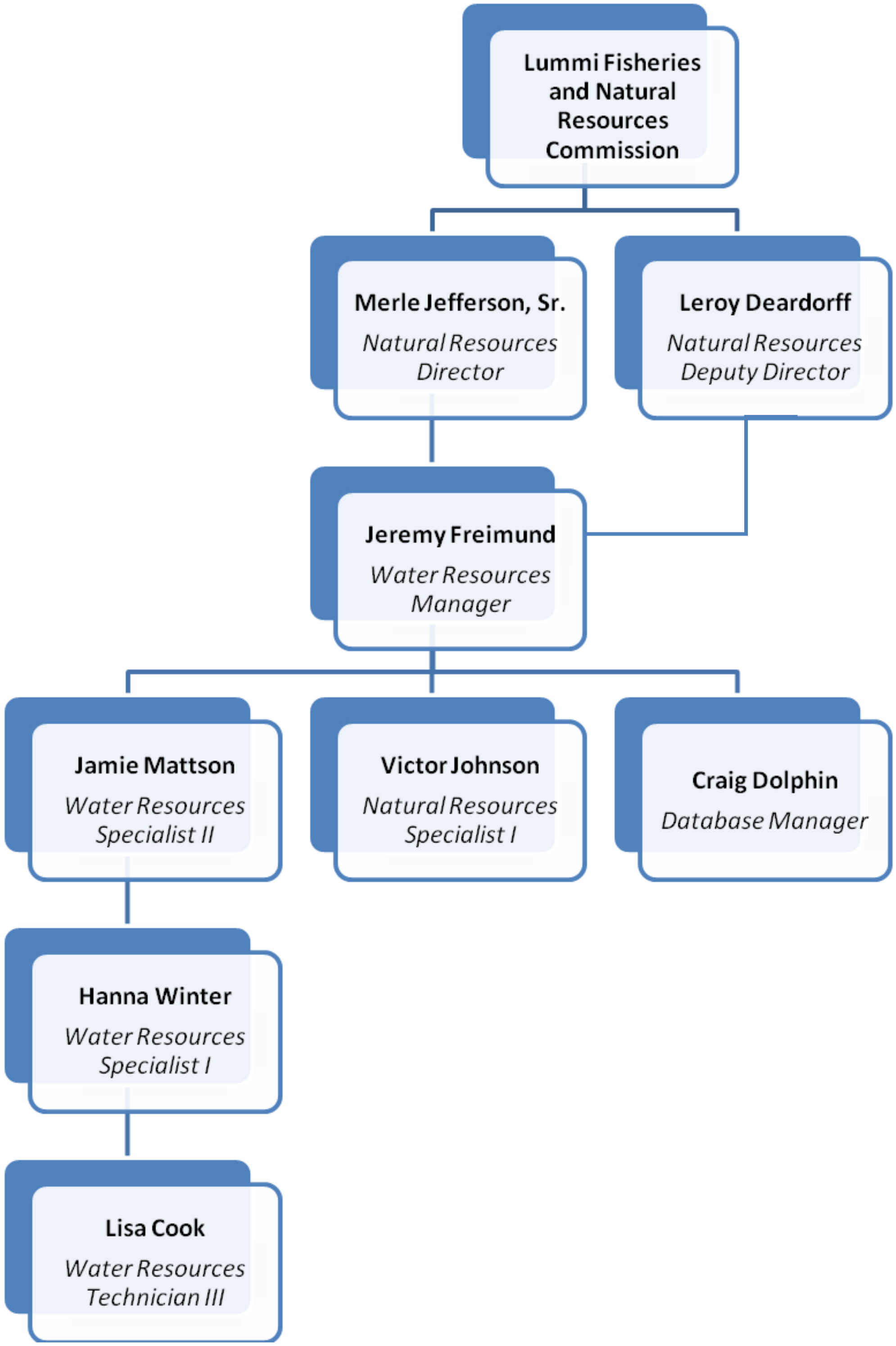

Figure 2.1 LNR Key Staff Involved In Continuous Temperature Monitoring Program

2.1 Special Training Requirements and Certification (A8)

The title, role, contact information, position requirements, and qualifications held by the current Water Resources Manager, Water Resources Specialist II, Water Resources Specialist I, and Water Resources Technician III are listed in Table 2.1.

Table 2.1 Lummi Water Resources Division Position Requirements

Title/Role/Contact	Position Requirements	Held Qualifications
Water Resources Manager, Project Manager and Quality Assurance Manager for the Lummi Water Quality Monitoring Program (360) 312-2314 jeremyf@lummi-nsn.gov	Master of Science degree in a related field (Lummi Nation Code of Laws 17.02.020)	Certified Professional Hydrologist (American Institute of Hydrology No. 1595), Master of Science degree in Watershed Management, Bachelor of Science degree in Zoology, 30 years professional experience.
Water Resources Specialist II, Quality Assurance Officer (360) 312-2313 jamiem@lummi-nsn.gov	Bachelor of Science degree in a related field, Master of Science highly desired but not required	Bachelor of Science degree in Environmental Science with emphasis on water quality and minor in geology, 9 years professional experience.
Water Resources Specialist I, Water Quality Program Coordinator (360) 312-2312 hannaw@lummi-nsn.gov	Bachelor of Science degree in environmental, physical, or one of the natural sciences	Master of Science degree in Environmental Science, Bachelor of Science degree in Environmental Science with emphasis on freshwater ecology and minor in environmental policy, 3 years professional experience.
Water Resources Technician III (360) 312-2324 lisac@lummi-nsn.gov	High school diploma or equivalent	Associate of Applied Science degree in Process Technology, currently attending classes toward Bachelor of Science degree in Native Environmental Science (expected graduation date March 2016), 19 years professional experience.

Additional training requirements are identified in Table 2.2. These requirements can be completed prior to or during employment in these positions. All of this information is retained in personnel files, and supervisors are responsible for ensuring staff are qualified and trained.

Table 2.2 Training Requirements (Water Resources Specialist and Technician Positions)

Required	Desired
• Health Care (Basic First Aid, Cardiopulmonary Resuscitation) • Computer Proficiency (Word Processing, Spreadsheet, Presentation, Database) • Boat Use and Safety • Incident Command System/National Incident Management System • Experience with or on-the-job training in: water quality sampling methods, groundwater sampling methods, quality assurance and quality control • 24-Hour Hazardous Materials Technician Training	• First Responder Awareness Training • First Responder Operations Training • Electrical Hazards and Safety Training • Global Positioning System applications • Construction Site Storm Water Management • Construction Site Storm Water Inspection • Management and Supervision • Geographic Information Systems applications • Project Design and Management • Environmental Regulations and Ethics • Hydrologist Technician Certification • Continuous Data Collection Methods/Protocol

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3. PROBLEM DEFINITION AND BACKGROUND (A5)

3.1 Program Summary

The Continuous Temperature Monitoring Program will provide continuous temperature data from ten surface water sites on the Reservation to determine whether these waters meet the Water Quality Standards for Surface Waters of the Lummi Indian Reservation (LWRD 2007).

Water temperature will be measured every 30 minutes at 10 sites, and rolling 7-day averages of the daily maximum water temperature (7DADM) for freshwater sites and 1-day maximum water temperature for marine water sites will be calculated. These temperatures will be compared with ambient water quality temperature criteria for the designated water quality class for the particular system monitored. The results of this program will advise regulatory actions, restoration efforts, and Total Maximum Daily Load development, as determined by the Water Resources Manager, Natural Resources Director, and Natural Resources Deputy Director.

3.2 Program Context

The mission of the LNR is to enhance, manage, and protect natural resources into perpetuity for the benefit of the Lummi People in accordance with the policy and procedures of the Lummi Nation. The LWRD is responsible for protecting, restoring, and managing Lummi Nation water resources in accordance with the policies, priorities, and guidelines of the Lummi Nation. The overall goal of the LWRD is to protect the treaty rights to water of sufficient quantity and quality to support both the purposes of the Reservation as a permanent, economically viable homeland for the Lummi People, and to support a sustainable harvestable surplus of salmon and shellfish.

The Continuous Temperature Monitoring Program is a component of the Lummi Nation Water Quality Monitoring Program, which is an important element of the Comprehensive Water Resources Management Program (CWRMP).[1] Related components of the CWRMP include the Nonpoint Source Pollution Management Program, Wellhead Protection Program, Storm Water Management Program, Wetland Management Program, and the Water Quality Standards Program. Two important milestones in the program development were in January 2004, with adoption of the Lummi Nation Water Resources Protection Code (Title 17 of the Lummi Code of Laws) and the August 2007 adoption of the Water Quality Standards for Surface Waters of the Reservation. The EPA approved the Water Quality Standards in September 2008.

The Continuous Temperature Monitoring Program will provide continuous temperature data from ten surface water sites on the Reservation to determine whether these surface waters meet the ambient water temperature criteria.

[1] The CWRMP was developed to ensure that the planning and development of Reservation water and land resources are safeguarded against surface and ground water degradation.

3.3 Project Location

The Lummi Reservation is located along the western boundary of Whatcom County and includes the deltas of the Nooksack and Lummi rivers. The Lummi River is a former distributary of the Nooksack River that empties into Lummi Bay and only receives water from the Nooksack River when Nooksack River flows are in excess of approximately 9,600 cubic feet per second (cfs). The Lummi River currently drains much of the area west of the Nooksack River in the vicinity of Ferndale, Washington (14 square miles). The Nooksack River drains most of western Whatcom County, including the developed lowlands (809 square miles). Both the Nooksack and Lummi river watersheds are under environmental pressures from rapid regional growth. The Lummi Nation is continuing to undergo a period of rapid economic development under self-governance. Growth on and near the Reservation requires that the Lummi Nation's core environmental programs prioritize the development of a regulatory infrastructure that is technically sound, legally defensible, administratively efficient, and that allows for growth while protecting tribal resources and the Reservation environment. The Lummi Reservation has approximately 38 miles of marine shoreline and approximately 10 miles of freshwater/estuarine shoreline along the Lummi and Nooksack rivers and deltas. Due to the estuarine environment, nearly all of the watercourses in the Lummi River and Nooksack River floodplains are exposed to marine influences, which include the presence of saline water, salinity-based stratification, and upstream flow during high tide. Most of the sample sites are tidally influenced (water level and/or salinity) and have variable water column profiles and salinities (*e.g.,* stratified or well-mixed).

3.4 Water Temperature

There are numerous threats to Lummi Nation Waters.[2] These threats are described in detail in the Lummi Nation Nonpoint Source Management Plan (LWRD 2002), the Lummi Nation Nonpoint Source Pollution Management Plan: 2015-2020 (LWRD 2015b) and other documents developed as part of the Lummi Nation CWRMP (LWRD 1997, 1998, 2000, and 2001) and associated updates (LWRD 2011a, 2011b, and 2015a). The Continuous Temperature Monitoring Program is focused on monitoring surface water temperatures for waters flowing onto the Reservation and within the Nooksack River.

Increases in water temperature can affect water quality and biotic communities, particularly salmonids, in several ways. Temperature is one of the most important parameters influencing salmonid biology. Because salmonids are poikilotherms, as are most aquatic organisms, their internal temperature and metabolism are determined by the ambient water temperature. Water temperature influences incubation and early fry development, growth and feeding rates, smoltification, swimming speed, and the timing of life history events such as upstream migration, spawning, freshwater rearing and seaward migration. Thermal stress can result from temperatures that are too warm, resulting in death or reduced fitness that impairs processes

[2] Pursuant to 17.09.010 of the Lummi Code of Laws, Lummi Nation Water includes all fresh and marine waters that originate or flow in, into, or through the Reservation, or that are stored on the Reservation, whether found on the surface of the earth or underground, and all Lummi Nation tribal reserved water rights.

such as growth, spawning, smoltification, or swimming speed (McCullough et al. 2001). Thermal stress can also block migration, create disease problems, and alter competitive dominance (Carter 2005). Higher temperatures also reduce the amount of dissolved oxygen available to aquatic organisms, potentially resulting in respiratory stress. In addition, elevated water temperature also increases the solubility of most metals and chemicals and reduces their adsorption to sediment particles, increasing pollutant concentrations within the water column.

Eighteen (18) waterbody segments in the Nooksack River watershed, including the Middle Fork and South Fork of the Nooksack River, are listed as impaired by high water temperature on the Washington State 303(d) list (Ecology 2012), and three segments are considered waters of concern. In Reservation waters monitored by LWRD in 2012, 100% (five of five) of the freshwater and 100% (four of four) of the marine sites exceeded the temperature water quality criterion for Class AA Extraordinary waters (LWRD 2015). A previous report suggested low flow and/or shallow water that had flowed over sun-warmed sediments or tideflats were likely causes of water quality violations (LWRD 2001). In addition, the likely primary causes of increased water temperatures in the Nooksack River and on the Reservation in general are reduced shading, altered channel structure (*e.g.,* wide, shallow streams), and loss of contributions from groundwater base flow, all three of which are due to agricultural practices, forestry, and land development (LWRD 2001).

3.5 Lummi Nation Surface Water Quality Standards

The Lummi Nation Surface Water Quality Standards detail four surface water classes (AA Extraordinary, A Excellent, B Good, and Lake Class) and their characteristic uses, and provides water quality criteria for a variety of parameters for each class. EPA approved these water quality standards in September 2008. Surface water quality criteria for temperature is measured as a seven-day average of the daily maximum value (7DADM) for freshwater and a one-day maximum for marine water. Class AA Extraordinary waters provide the greatest number of characteristic uses, including salmonid migration, juvenile rearing, spawning, egg incubation, and fry emergence, and therefore have the most stringent water temperature criterion. Class AA Extraordinary freshwater temperature may not exceed a 7DADM of 16.0°C or, for summertime spawning, a 7DADM of 13.0°C. Marine waters considered Class AA Extraordinary may not exceed a 1-day maximum temperature of 13.0°C. Class A Excellent waters support salmonid migration and juvenile rearing, but not critical uses such as salmonid spawning, egg incubation and fry emergence. Class A Excellent freshwaters may not exceed a 7DADM temperature of 17.5°C, while Class A marine waters may not exceed a 1-day maximum temperature of 16.0°C. Class B Good waters also support salmonid migration and juvenile rearing, but do not support clam, oyster, mussel, crustacean, or other shellfish harvesting. Class B Good freshwaters may not exceed a 7DADM temperature of 17.5°C and marine waters may not exceed a 1-day maximum temperature of 19.0°C. See Table 3.1 for details on the characteristic uses and temperature criteria for each surface water class.

Table 3.1 Lummi Nation Surface Water Quality Standards Characteristic Uses and Temperature Criteria (LWRD 2007)

Class AA Extraordinary	Class A Excellent	Class B Good	Lake Class
Characteristic Uses			
(A) Water supply (domestic, commercial, municipal, industrial, agricultural). (B) Stock watering. (C) Fish and shellfish: Salmonid migration, juvenile rearing, spawning, egg incubation, fry emergence, and harvesting. Other fish migration, juvenile rearing, spawning, egg incubation, fry emergence, and harvesting. Clam, oyster, and mussel rearing, spawning, and harvesting. Crustaceans and other shellfish (crabs, shrimp, crayfish, scallops, geoduck, etc.) rearing, spawning, and harvesting. (D) Wildlife habitat. (E) Recreation (extraordinary primary contact, primary contact, sport fishing, boating, canoeing, and aesthetic enjoyment). (F) Commerce and navigation. (G) Tribal Cultural.	(A) Water supply (domestic, commercial, municipal, industrial, agricultural). (B) Stock watering. (C) Fish and shellfish: Salmonid migration, juvenile rearing, and harvesting. Other fish migration, juvenile rearing, spawning, egg incubation, fry emergence, and harvesting. Clam, oyster, and mussel rearing, spawning, and harvesting. Crustaceans and other shellfish (crabs, shrimp, crayfish, scallops, geoduck, etc.) rearing, spawning, and harvesting. (D) Wildlife habitat. (E) Recreation (primary contact, sport fishing, boating, canoeing, and aesthetic enjoyment). (F) Commerce and navigation. (G) Tribal Cultural.	(A) Water supply (industrial, agricultural). (B) Stock watering. (C) Fish and shellfish: Salmonid migration, juvenile rearing, and harvesting. Other fish migration, juvenile rearing, spawning, egg incubation, fry emergence, and harvesting. Clam, oyster, and mussel rearing, and spawning. Crustaceans and other shellfish (crabs, shrimp, crayfish, scallops, geoduck, etc.) rearing, and spawning. (D) Wildlife habitat. (E) Recreation (secondary contact, sport fishing, boating, canoeing, and aesthetic enjoyment). (F) Commerce and navigation. (G) Tribal Cultural.	(A) Water supply (domestic, commercial, municipal, industrial, agricultural). (B) Stock watering. (C) Fish and shellfish: Salmonid migration, juvenile rearing, spawning, egg incubation, fry emergence, and harvesting. Other fish migration, juvenile rearing, spawning, egg incubation, fry emergence, and harvesting. Clam and mussel rearing and spawning. Crayfish rearing and spawning. (D) Wildlife habitat. (E) Recreation (extraordinary primary contact, primary contact, sport fishing, boating, canoeing, and aesthetic enjoyment). (F) Commerce and navigation. (G) Tribal Cultural.
Freshwater Temperature			
Shall not exceed a 7-day average of the daily maximum value (7DADM) temperature of 16.0°C. For summertime spawning, temperature shall not exceed a 7DADM temperature of 13.0°C.	Shall not exceed a 7DADM temperature of 17.5°C.	Shall not exceed a 7DADM temperature of 17.5°C.	No measurable increase from natural conditions.
Marine Water Temperature			
Shall not exceed a 1-day maximum temperature of 13.0°C	Shall not exceed a 1-day maximum temperature of 16.0°C	Shall not exceed a 1-day maximum temperature of 19.0°C	N/A

3.6 Project Justification

Prior to 2009, the Surface Water Quality Monitoring Program only involved collection of single measurements of water temperature at each site during a sampling run; typically once per month per site. Because the water quality standards are expressed as the 7-day average of the daily maximum (7DADM) water temperature for freshwater sites and as the 1-day maximum water temperature for marine water sites, continuous temperature monitoring is needed to accurately evaluate compliance of waters flowing onto and within the Reservation with the Lummi Nation Water Quality Standards.

Between 2009 and 2013, continuous temperature monitoring loggers were deployed at ten surface water monitoring sites. The collected data were to be used for informational purposes only as there were no approved QA/QC procedures in place during that time. It is noted that the continuous temperature monitoring probes/data loggers were deployed and operated pursuant to manufacturer instructions but a formal QAPP was not developed due to work load and time constraints. This QAPP will provide the QA/QC procedures needed to verify the quality of the data collected under this program in order to use data collected for evaluation of trends, impairment, and compliance with water quality criteria.

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4. PROJECT DESCRIPTION (A6) AND EXPERIMENTAL DESIGN (B1)

The Lummi Nation Surface Water Quality Monitoring Program has been ongoing since 1993. The Continuous Temperature Monitoring Program was launched in 2009, when continuous temperature loggers were deployed at ten monitoring sites.

The objectives of the Continuous Temperature Monitoring Program are:

- To establish the baseline conditions of surface waters on and flowing onto the Reservation;
- To use this information to evaluate regulatory compliance of waters flowing onto and through the Reservation; and
- To support the development and implementation of a water quality regulatory program (*e.g.,* Lummi Code of Laws Title 17, Water Quality Standards) on the Reservation.

Specifically, this program will provide data to determine whether surface waters on the Reservation meet the ambient water temperature criteria for the assigned water quality class for that particular system. Six Class AA freshwater and four Class AA marine water sites were selected for continuous temperature monitoring under this program. See Table 4.1 and Figure 4.1 for details on the selected monitoring sites. One of the sites will also be used as a continuous air temperature monitoring site (site SW011) to provide a measure of air temperature on the Reservation concurrent with water temperature measurements. Air temperature is monitored to provide a comparison with water temperature measurements, and to assist in identification of data errors such as may occur when a water temperature logger becomes dewatered.

Upon approval of this QAPP, the continuous temperature loggers will continue to be deployed at the ten monitoring sites listed in Table 4.1 following the procedures outlined in Section 7 of this QAPP. The loggers will be programmed to record a temperature measurement every 30 minutes. The temperature data will be downloaded from each logger on a quarterly basis: in December, March, June and September. Daily running seven-day averages of the daily maximum temperature (7DADM) will be calculated for each freshwater site and 1-day maximum temperature will be calculated for each marine water site. These will be compared to the temperature criteria for each designated class, as listed in the Lummi Nation Surface Water Quality Standards. The annual temperature data and comparison to the Surface Water Quality Standards will be included in the annual Water Quality Assessment Report, which will be transmitted to the EPA by March 31 of the following calendar year upon approval by the Water Resources Manager and the Deputy Director of the LNR.

QA/QC procedures include manufacturer calibration or logger replacement as specified in the equipment Standard Operating Procedures (SOP), annual two-point laboratory accuracy checks, and quarterly field accuracy checks with a reference temperature probe or field thermometer. Details of the QA/QC procedures are provided in Section 8.

Table 4.1 Continuous Temperature Monitoring Sites

Sample Site ID	Sample Site Name	Water Class Designation
SW003	Jordan Creek at North Red River Road	Class AA Freshwater
SW008	Lummi River at Hillaire Road Bridge	Class AA Marine Water
SW009	Lummi River at Slater Road	Class AA Freshwater
SW011	Jordan Creek at Slater Road	Class AA Freshwater
SW012	Schell Creek at Slater Road	Class AA Freshwater
SW015	Smuggler’s Slough at Lummi Shore Drive	Class AA Freshwater
SW051	Lummi River Mouth	Class AA Marine Water
SW053	North Lummi River Distributary Mouth	Class AA Marine Water
SW059	Smuggler’s Slough at Kwina Road	Class AA Marine Water
SW118	Nooksack River at Marine Drive Bridge	Class AA Freshwater

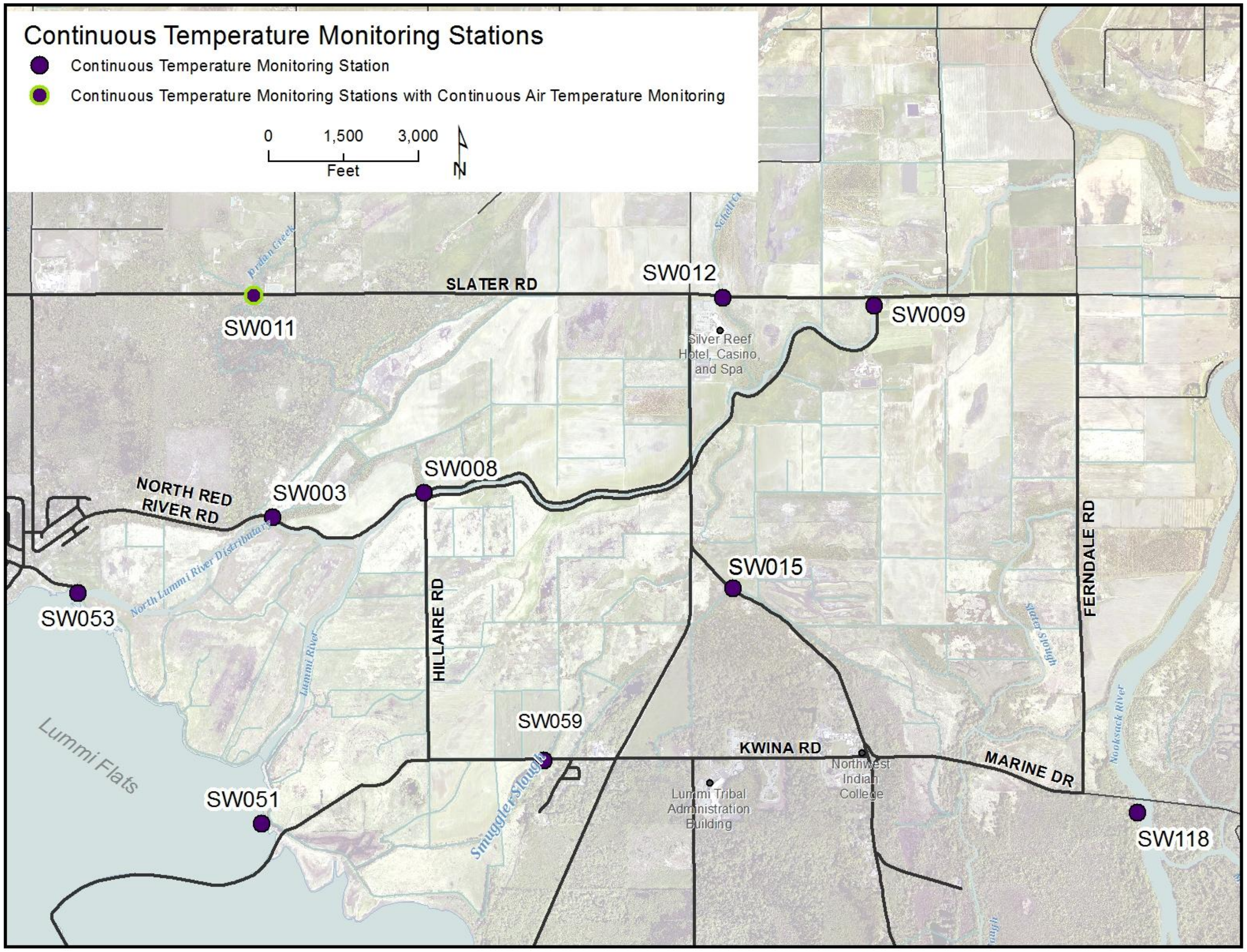

Figure 4.1 Location of Continuous Temperature Monitoring Sites

4.1 Design Justification

The monitoring sites were selected to represent four systems: the North Lummi River Distributary (SW003, SW011, SW053), the Lummi River (SW008, SW009, SW012, SW051), Smuggler's Slough (SW015, SW059) and the Nooksack River (SW118). These sites are routinely sampled monthly (or more frequently for Sites SW051 and SW118) as part of the Ambient Surface Water Quality Monitoring Program. Site SW011 was selected for continuous air temperature monitoring to provide air temperature measurements for comparison with the water temperature measurements, and to assist in identification of logger dewatering events. Site SW011 is relatively secluded and is forested, resulting in cooler air temperatures due to shading from solar radiation. Table 4.2 presents further details on the rationale for selecting sites for continuous temperature monitoring.

Table 4.2 Rationale of Site Selection for Continuous Temperature Monitoring Program

Site ID	Description	Drainage/System	Rationale for Continuous Temperature Monitoring
SW003	Jordan Creek at North Red River Road	North Lummi River Distributary	Jordan Creek is a freshwater tributary to the North Lummi River Distributary. Site SW003 characterizes Jordan Creek upstream of the confluence of Jordan Creek and the North Lummi River Distributary main stem.
SW008	Lummi River at Hillaire Road Bridge	Lummi River	The Lummi River at site SW008 is considered a marine water site because it is inundated with marine water during high tides. This site represents the Lummi River downstream of the confluence of Schell Creek and the Lummi River main stem.
SW009	Lummi River at Slater Road	Lummi River	Site SW009 characterizes the Lummi River as it enters the Reservation.
SW011	Jordan Creek at Slater Road	North Lummi River Distributary	Jordan Creek is a freshwater tributary to the North Lummi River Distributary. Site SW011 characterizes Jordan Creek as it enters the Reservation. This site was also selected for continuous air temperature monitoring due to its secluded location and forest cover.
SW012	Schell Creek at Slater Road	Lummi River	Schell Creek is a freshwater tributary to the Lummi River. Site SW012 characterizes the tributary as it enters the Reservation.
SW015	Smuggler’s Slough at Lummi Shore Road	Smuggler’s Slough	Smuggler’s Slough flows into Lummi Bay at tide gates near the mouth of the Lummi River. This drainage is 100% contained within the Reservation. SW015 is a freshwater site.
SW051	Lummi River Mouth	Lummi River	Site SW051 characterizes the Lummi River as it discharges into Lummi Bay.
SW053	North Lummi River Distributary Mouth	North Lummi River Distributary	Site SW053 characterizes the North Lummi River Distributary as it discharges into Lummi Bay.
SW059	Smuggler’s Slough at Kwina Road	Smuggler’s Slough	Smuggler’s Slough flows into Lummi Bay at tide gates near the mouth of the Lummi River. This drainage is 100% contained within the Reservation. SW059 is a marine site located within Area B of the Blockhouse Site for the Lummi Nation Wetland and Habitat Mitigation Bank.
SW118	Nooksack River at Marine Drive Bridge	Nooksack River	The Nooksack River drains 809 square miles of Whatcom and Skagit Counties into Bellingham Bay. Site SW118 characterizes the river upstream of its delta.

4.2 Alternate Sites

In the event that continuous temperature data are available for any of the selected sites listed above from another source,[3] the continuous temperature loggers from those sites are redeployed to alternate, additional locations. Duplication of data collection is avoided to conserve resources and maximize the dataset of continuous temperature data. The alternate site will be selected based on representativeness, water quality concerns, and feasibility of deployment and site access.

Alternate sites include (Figure 4.2):

- Portage Island (*e.g.,* SW027)
- Sandy Point Marina (*e.g.,* SW001, SW019)
- SW029
- Seaponds Aquaculture Facility (*e.g.,* DOH044, DOH045)
- Nooksack River Delta (*e.g.,* fish point boat launch near Howard's and Native American Seafoods)

[3] Continuous temperature monitoring is conducted by other divisions within the LNR. As of July 2015, the Restoration Division is planning to conduct year-round continuous temperature monitoring at several sites within Smugglers Slough and connected waterways. If continuous temperature sensors are deployed by the Restoration Division, LWRD staff responsible for implementing this QAPP will work with Restoration staff to ensure that continuous temperature data collected by Restoration Division staff can be used in addition to data collected under this QAPP. If continuous temperature loggers are deployed by the Restoration Division in a location listed as a continuous temperature monitoring site in this QAPP, LWRD staff will not deploy a continuous temperature logger at that location to avoid duplication of data collection efforts. An alternate site will be selected under these circumstances.

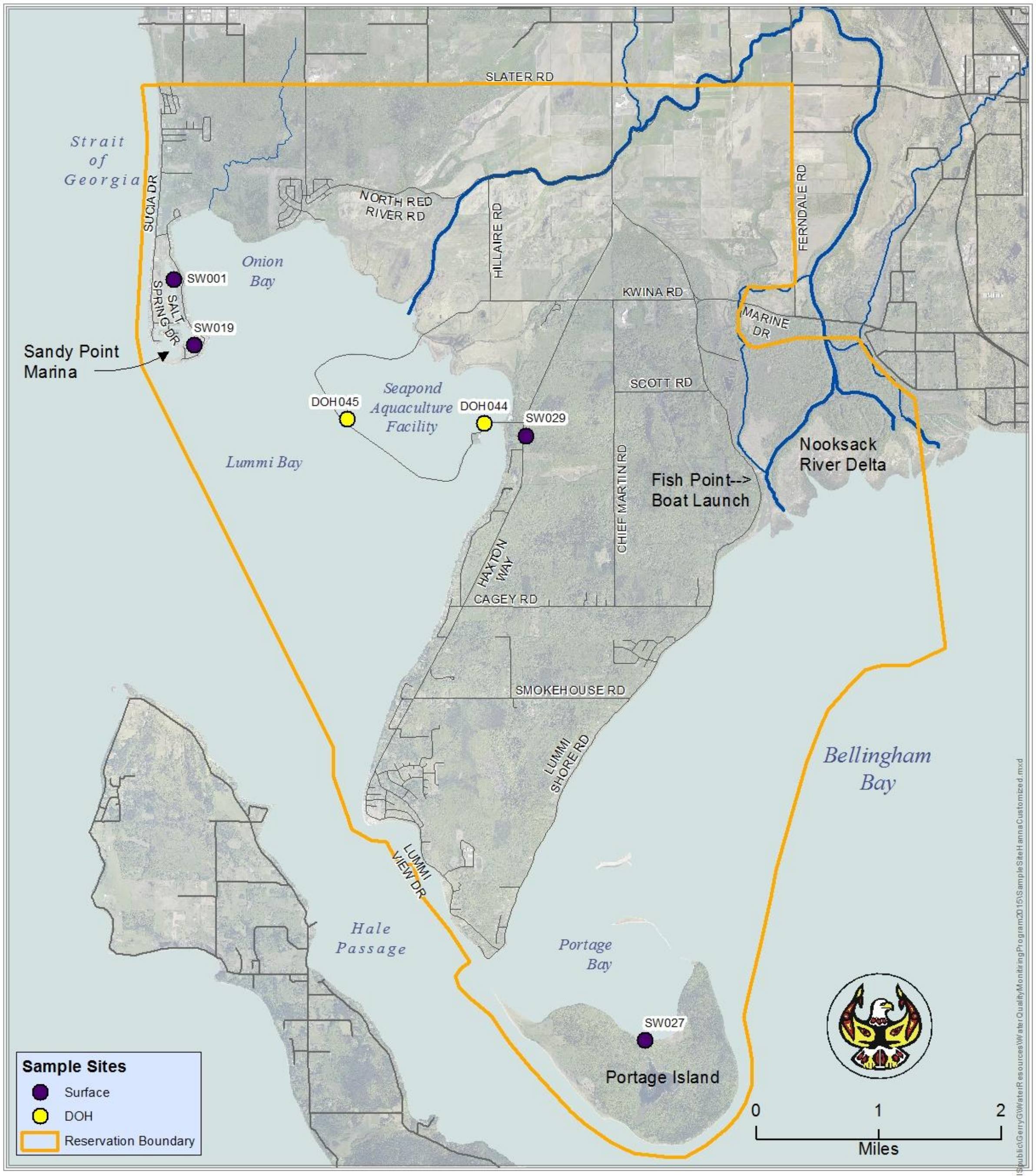

Figure 4.2 Alternate continuous temperature monitoring sites

4.3 Project Timeline

Upon approval of this QAPP, the Continuous Temperature Monitoring Program will be implemented following the estimated timeline below.

Table 4.3 Estimated Timeline for Task Implementation

Task	Estimated Timeline
Approval of QAPP	September 2015
Pre-deployment accuracy check of continuous temperature loggers and preparation for re-deployment	September 2015
Deployment of continuous temperature loggers	September 2015
Initial verification of deployment methods	October 2015
Field accuracy check and data download	December 2015, March 2016, June 2016, September 2016 and each quarter thereafter
Annual lab accuracy check	September 2016 and annually thereafter
Data analysis and report writing	January-March annually
Inclusion of data summary and analysis in Annual Water Quality Assessment Report	March 31 annually

5. QUALITY OBJECTIVES AND CRITERIA FOR MEASUREMENT DATA (A7)

The overall performance standard for the Continuous Temperature Monitoring Program is the collection of high-quality continuous temperature data sufficient to meet program goals. Data must be of sufficient quality (*i.e.,* known precision, accuracy, bias, traceability, completeness, and representativeness) to support decisions based upon the water quality data. Quality control activities are designed to indicate data quality prior to logger deployment or mid-deployment in the field and prompt corrective actions at that time, if necessary. In addition, quality control activities provide information necessary to assess and quantify data quality and comparability for data analysis.

The Continuous Temperature Monitoring Program is ongoing and is not designed to prove or disprove a specific hypothesis. The data are used to assist in identifying and addressing actual and potential impairments of water quality and for evaluation of water temperature trends against regulatory criteria. Quality control activities are in place to ensure the reliability and usefulness of the temperature data for evaluation of trends, impairment, and compliance with water quality criteria.

Running 7DADM and 1-day maximum temperatures will be systematically calculated for each freshwater and marine site, respectively. Calculation of these values will become routine with implementation of data verification and validation protocols associated with the database. It is anticipated that additional statistics will be systematically calculated in order to aid with data screening and identification of data errors (see Section 9.2) and data correction (see Section 9.3).

5.1 Objectives and Project Decisions

As described previously, the objectives of the Continuous Temperature Monitoring Program are:

1. To establish the baseline conditions of surface waters on and flowing onto the Reservation;
2. To use this information to evaluate regulatory compliance of waters flowing onto and through the Reservation; and
3. To support the development and implementation of a water quality regulatory program (*e.g.,* Lummi Code of Laws Title 17, Water Quality Standards) on the Reservation.

Specifically, this program will provide data to determine whether surface waters flowing onto and within the Reservation meet the ambient water temperature criterion for the assigned water quality class for that particular system.

5.2 Measurement Performance Criteria/Acceptance Criteria

Quality assurance/quality control (QA/QC) procedures include calibration by the manufacturer, a pre-deployment accuracy check, field accuracy checks, and an annual laboratory accuracy check (see Section 8). The continuous temperature logger standard operating procedures (SOP) lists QA/QC procedures and maintenance requirements specific to the temperature loggers (see Appendix B).

The acceptance criterion for annual deployment of continuous temperature loggers is ±0.2°C, and for quarterly QA/QC validation is ±0.5°C. If a pre-deployment or annual laboratory accuracy check reveals the difference between the reference temperature and the measured temperature is greater than ±0.2°C, corrective actions will be taken or the instrument will be returned to the manufacturer for recalibration or replacement (see Sections 8.2 and 8.4). If a field accuracy check reveals greater than ±0.5°C difference between true temperature and measured temperature, corrective actions will be taken and data will be corrected or data will be marked as suspect (see Section 8.3). Please see Section 8.8 for details about corrective actions.

5.3 Precision

Precision will be evaluated during accuracy checks by collecting several temperature measurements within a short period of time. Average difference from the known temperature (as measured by NIST-traceable thermometer) and standard error will be calculated to determine precision. Although ideal for determining data precision, deployment of two loggers per site is not practical due to budget limitations.

Manufacturer-stated resolution for the continuous temperature logger is listed in the SOP for the logger.

5.4 Accuracy and Bias

The accuracy of the continuous temperature loggers is specified by the manufacturer (see SOP attached as Appendix B). The continuous temperature loggers will be calibrated by the manufacturer and accuracy will be verified annually in the lab at representative temperatures (0 and 20°C) and quarterly in the field at ambient temperatures. A NIST-traceable thermometer or independent reference probe calibrated and verified against a NIST-traceable thermometer will be used for all accuracy checks (see Section 8.7 for specific requirements of the reference thermometer). If the logger does not meet the validation acceptance criterion (±0.2°C in the lab or ±0.5°C in the field), corrective actions will be taken to determine and remedy the problem (see Section 8.8 for corrective actions).

5.5 Representativeness

Temperature loggers will be deployed in locations representative of the aquatic system to be monitored. The following considerations will be taken into account when choosing a representative location for temperature logger installation:

- Low flow or low tide conditions: the logger will need to be installed in a location where it will remain under water during all flow and tide conditions.
- Potential for burial in sediment: the logger will need to be installed in a location where it will remain above the stream bottom during all flow and tide conditions. High flows can cause loggers to be covered with sediment.
- Thermal stratification (vertical or horizontal) and mixing zones: the logger will need to be installed in a location without thermal stratification.
- Where have samples been collected historically? If all else is equal, the logger will be placed in a location as near as practical to the location where samples are collected as part of the Ambient Surface Water Quality Monitoring Program.

If variation is present, it is recorded on the field datasheet. Variation can also be representative of water quality due to the variable nature of surface waters on the Reservation.

5.6 Comparability

With implementation of the Continuous Temperature Monitoring Program, ongoing temperature data will be collected for the ten selected sites. Upon data validation and verification, year to year temperature data from this program can be used to describe temperature trends at each site.

Continuous temperature monitoring will be conducted at sites that are a part of the Ambient Surface Water Quality Monitoring Program. Water quality parameters (temperature, pH, salinity, conductivity, dissolved oxygen and bacteria [fecal coliform, *Escherichia coli*, *Enterococcus*]) are measured on a monthly basis from a representative location at these sites. Continuous temperature monitoring data can also be compared to the *in situ* water temperature data collected at these sites.

Continuous temperature data collected by other LNR departments (*e.g.,* Restoration Division) may be used to provide supplemental temperature data for additional sites on the Reservation. If the temperature data were collected following an approved QAPP, these data may be used in addition to the data collected under this QAPP to determine whether these waters meet the Surface Water Quality Standards.

The U.S. Geological Survey (USGS) maintains a gaging station on the Nooksack River at Ferndale (USGS 12213100) with temperature data available as daily minimum, maximum and average. Continuous temperature data collected at site SW118 (Nooksack River at Marine Drive Bridge) may be compared to the Nooksack River gage at Ferndale to describe the general temperature conditions in the Nooksack River.

5.7 Completeness

The goal of the Continuous Temperature Monitoring Program is to collect temperature data from each of the ten selected sites every 30 minutes year-round. Data gaps may affect future analysis of baseline conditions and comparison to regulatory criteria, but do not immediately compromise the integrity of the monitoring program because the monitoring is not attempting to answer a specific hypothesis. Data gaps are addressed on a case-by-case basis. Missing data may be due to staff turnover, resource constraints, equipment failure, corrective actions, and logistical problems. Corrective actions are undertaken to remedy conditions that create missing data to prevent data gaps in the future (see Section 8.8).

5.8 Range/Sensitivity

The sensitivity of the temperature data collected and range of temperatures that can be measured will depend on the equipment selected. The goal is to maintain a minimum resolution of ±0.2°C within the typical range of temperatures for surface waters on the Reservation (0-25°C).

6. DOCUMENTS AND RECORDS (A9)

6.1 Quality Assurance Project Plan Distribution

The Water Resources Specialist I is responsible for ensuring that the people listed on the Distribution List in Section 1 (A3) have the most current version of this QAPP. Records will be maintained by the Water Resources Specialist I documenting substantial and minor version changes as well as the distribution of minor change letters and revised Project Plans.

Substantial QAPP updates will be transmitted to the EPA Project Manager and EPA Quality Assurance Officer for approval as an entire document with identification and justification of changes. Major updates will result in a change in the number before the decimal point in the QAPP version number (*e.g.,* change of name from Version 1.0 to 2.0).

Minor updates to the QAPP will be transmitted to the EPA Project Manager and EPA Quality Assurance Officer for approval via a letter that identifies changes and justifications. Minor updates include correction of mistakes and non-substantial changes to the QAPP. Corrections of mistakes are tracked through the use of a lower case letter at the end of the QAPP version number (*e.g.,* change of name from Version 1.0 to 1.0a). Non-substantial minor changes are tracked through change of the number following the decimal point in the QAPP version number (*e.g.,* change of name from Version 1.0 to 1.1).

QAPP updates and revision letters will be provided to the individuals in the distribution list via electronic format.

6.2 Documentation and Records

All accuracy check details, logger information, stream cross-section surveys, and field notes will be recorded in Excel datasheets on the field computer or on datasheets printed on write-in-the-rain paper in ink or pencil. In the future, notes and accuracy check details may be entered directly into the continuous temperature monitoring database using an iPad (or equivalent) remotely connected to the LIBC servers when remote connection is available. Continuous temperature logger data will be downloaded onto a field laptop and backed up on a flash drive prior to upload to secure LIBC servers.

All accuracy check information will be recorded, including: logger and reference thermometer identification information, measurement times, logger temperature readings, reference thermometer readings, and calculations. All field notes will be recorded, including: name(s) of person(s) performing the work, site identification, site description (including a sketch or photos, if applicable), logger deployment notes, logger deployment location, time of deployment (note daylight savings time or standard time), time of data download, physical description of logger (including any fouling observed), quality control activities, and corrective actions. Maintenance activities, calibrations and replacement of loggers will be recorded in the maintenance database. Datasheets for lab and field accuracy checks are included in Appendix E.

Datasheets are saved as Excel templates. Cells containing calculations are protected to prevent accidental changes. Datasheets are opened as copies of the Excel template and resaved following the format: date (yyyymmdd), underscore, CTM_Datasheets (*e.g.,* 20150522_CTM_Datasheets). Datasheets are saved as Excel spreadsheets and PDF files in the Digital Archive H:\Natural Resources\DA_WaterResources\SurfaceWaterData under the appropriate year and month folders.

Errors on the paper field datasheets are crossed out with one line and the date of the correction and initials of the person(s) that made the correction recorded. Data and field notes recorded on paper datasheets will be transferred to the database upon return to the office from the field, and data and notes entered will be checked by the Water Resources Specialist I for accurate data entry. Datasheets and QA/QC reports are scanned and saved in the appropriate electronic folder on the LIBC server, and physical copies are hole-punched and stored chronologically in a 3-ring binder maintained by the Water Resources Specialist I in the LWRD office. All electronic data are stored on the LIBC network hard drive that is backed up nightly.

The Project Manager will maintain, or will delegate maintenance of, paper and/or electronic files of relevant project documents, including:

- Current (and past archived) QAPPs.
- Manuals for the temperature data loggers and associated interface software.
- Temperature Data Logger maintenance database to track data logger performance and plan servicing.
- Field and QA/QC forms and notes, including:
    - Pre-deployment accuracy check forms.
    - Deployment field notes, site photos, and sketches.
    - Quarterly field accuracy check forms.
    - Stream cross-section survey forms.
- Annual laboratory accuracy check forms.
- Downloaded data.
- Excel spreadsheets of raw and QA/QC data with appropriate QA/QC metadata.
- Annual Water Quality Assessment Reports.
- Records of submission to EPA STORET database.

6.3 Annual Reports

Results of the Continuous Temperature Monitoring Program will be included in the annual Water Quality Assessment Report, which summarizes the results of the Surface Water Quality Monitoring Programs implemented by the Lummi Water Resources Division. The reports determine whether water quality criteria are achieved and include graphical time-series analysis of water quality data for the reporting period as well as for the period of record. Daily 7DADM will be reported for freshwater sites and 1-day maximum temperature will be reported for marine sites. The report is provided to the EPA Project Officer by March 31 of the subsequent calendar year, following approval by the Water Resources Manager and the Natural Resources Deputy Director.

Continuous Temperature Monitoring data will also be transmitted to the EPA for inclusion in the STORET Data Warehouse via upload to the Water Quality Exchange (WQX) upon approval by the Water Resources Manager and the Natural Resources Deputy Director.

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7. LOGGER DEPLOYMENT AND DATA COLLECTION (B2 SAMPLING METHODS)

7.1 Safety

All field work will be conducted by teams of two or more. All procedures listed in the Lummi Water Resources Division Health and Safety Plan will be followed while conducting laboratory and field work outlined in this QAPP.

7.2 Deployment Location

7.2.1 Representative Location

Loggers will be deployed in a representative location at the monitoring site. A representative location should have the following attributes:

1. Well mixed – the site should not be thermally stratified at any time of year.
    a. Determine whether thermal stratification occurs during different seasons and flows. Horizontal and vertical stratification is checked a minimum of twice per year. See Section 7.2.2 for details.
    b. Consider effect of groundwater, storm water, and tributary contributions into the stream.
    c. Do not deploy loggers in stagnant water, eddies, backwater, reverse flows, areas of faster than normal flow, or any other features that could affect water temperature.
2. Accessible – the site should be safely accessible at all times of year.
3. Sufficient depth – the logger needs to be underwater at all times, including times of very low flow. The site will be selected to ensure that the logger is covered by 12 inches of water at all times. Some sites may have less than 12 inches of water at low flows; in these situations, the deepest location will be selected or a new site will be selected.
4. Avoid sedimentation – the logger needs to be above the stream bed at all times. High flow events can cause sediment buildup at the stream bottom, leading to burial of the logger in sediment. This can bias temperature readings, and should be avoided by placing the logger in a location at least 6 inches above the stream bottom, if practical.
5. Secure –
    a. The site should be in a location that is not readily obvious to passersby, due to the potential for vandalism or people who are curious and may remove the logger from the water, inadvertently exposing it to air and compromising the quality of the data collected by the logger.

b. The site should be in a location where the logger can be securely attached to the stream bottom or bank.

7.2.2 Cross-Section Survey

All continuous temperature monitoring sites are checked for vertical and horizontal variability twice annually to ensure that the continuous temperature loggers are deployed in a representative location. Temperature is measured at five horizontal locations on a cross-section of the stream or river at the logger deployment site. At each horizontal location, temperature is measured at a minimum of two depths. If horizontal or vertical variability in the temperature readings is present, a formal cross-section stream survey is required.

Cross-section stream surveys using the Equal Width Increment (EWI) method are conducted at sites where horizontal and/or vertical temperature variability is identified during twice-annual checks. Stream width is measured using a metal measuring tape (or other non-stretching measuring device), and divided into a minimum of 5 horizontal increments. Depth is measured in the mid-point of each horizontal increment.

The size of the vertical increment is selected depending on stream depth. The size of the vertical increment should be the same for each horizontal increment, but the number of vertical increments in each horizontal increment will depend on the depth. A minimum of two vertical increments are required. Temperature is measured in the top 12 inches of the mid-point of each horizontal increment for the first (surface) vertical increment and in the middle of each of the subsequent vertical increments (see Figure 7.1). The mean and standard deviation are calculated to determine representativeness of logger location in comparison to the full stream cross-section.

If the stream does not have sufficient depth, no vertical increments are needed; only horizontal representativeness and variability can be determined. Calculate mean and standard deviation to determine representativeness of logger location in comparison to the full stream cross-section. Survey information will be logged into an Excel datasheet that will automatically calculate mean and standard deviation (see Appendix E).

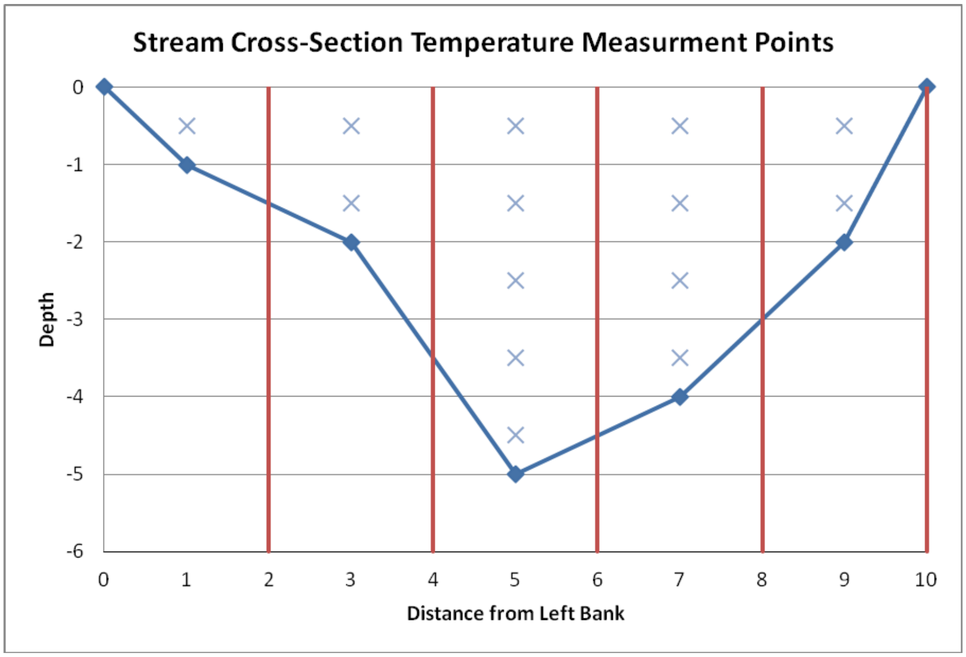

Figure 7.1 Schematic of temperature measuring points in cross-section stream survey. Temperature readings collected at evenly spaced horizontal and vertical increments to determine representativeness of logger deployment location.

7.3 Logger Preparation for Deployment

7.3.1 Protective Housing

All loggers are fitted with a protective housing to reduce solar radiation and damage. Loggers are placed inside a length of PVC pipe with holes. The holes allow water to flow through the protective housing while the PVC pipe protects the logger from loose gravel, rocks and other debris that may damage the logger and shades it from solar radiation. See Appendix C for details on protective housing construction and specifications, and Appendix B for Standard Operating Procedures (SOP).

The protective housing includes an engraved, aluminum tag with LWRD's contact information. In the event that the logger and protective housing are separated from the cable or rebar and are found, the logger can be returned to the LWRD.

7.3.2 Pre-Deployment QA/QC

QA/QC procedures are required prior to logger deployment. See Section 8.2 for details.

7.3.3 Logger Set-Up

The loggers are programmed to log a temperature measurement every 30 minutes. See logger SOP in Appendix B for details.

7.4 Deployment Strategy

Several logger deployment options are considered for each site and the most appropriate and feasible option selected. This means that the same deployment method may not be used at all sites (see Appendix D for deployment techniques).

7.4.1 Rebar

Bent rebar (approximately 4 feet in length, with one longer leg than the other) is driven into the stream bottom deep enough to stay in place during high flows. The logger, encased in its protective housing, is attached to the rebar by cable ties or wire with the enclosed end of the protective housing facing upstream or up toward the water surface.

7.4.2 Cable

Heavy-duty (*e.g.,* 120-lb tensile strength) cable is attached to rebar or stable instream structures such as large rocks/boulders, roots, woody debris, or a cinder block placed in the stream. Alternatively, the cable can be attached to a stable structure on the stream bank and extended into the stream. The logger, encased in its protective housing, is attached to the cable using cable ties or wire at two points with the enclosed end of the protective housing facing upstream.

7.4.3 Cinder Block

The logger, encased in its protective housing, is attached to the top or side of a cinder block using zip ties or wire. The logger is placed with the enclosed end of the protective housing facing upstream or up toward the water surface. The cinder block is connected to a stable structure on the stream bank for additional security for sites with periodic high flows.

7.4.4 Custom Block

The logger is attached to custom-built block if there is the potential for the logger to be buried in sediment. The locations must have sufficient water depth at low flows to avoid dewatering the logger with this deployment method as the logger will sit higher in the water column. The logger is attached to two eyelets in the block using cable ties or wire with the enclosed end of the protective housing facing upstream. The block is placed in the stream and a cable is attached to a third eyelet, which is attached to rebar or a stable structure instream or on the stream bank.

7.4.5 Weight and Buoy

At sites with sufficient water depth at low flows and considerable sedimentation along the stream bed, a weight and buoy combination can be used to keep the logger low in the water column but above the stream bottom. A large brick or cinder block is attached to a cable that is secured to a stable structure on the stream bank. A second cable (approximately 2-3 feet in length) from the brick or cinder block is secured to a foam buoy. The brick or cinder block and buoy must be appropriately sized so that the buoy does not pull the brick into the water column from the stream bottom. The logger, encased in its protective housing, is attached to the buoy or to the buoy line with the enclosed end of the protective housing facing up toward the water surface.

7.4.6 Air Temperature

The air temperature logger is also encased in a protective PVC housing to protect it from debris and solar radiation. The logger is attached to a tree within 10 feet of the stream bank as near as possible to the water temperature logger deployed at the same location. The logger is attached to the tree using cable ties or wire at two points. The selected site should be accessible by field crew, but not readily visible by passersby. A shady site is selected for air temperature logger deployment and the logger attached in a way that reduces solar radiation effects on the temperature measurements.

7.4.7 Canopy Cover

Canopy cover at the deployment site is measured using a spherical densiometer. Densiometer readings are taken as near to the continuous temperature logger deployment location as feasible following procedures provided by the manufacturer. Four readings are taken around the deployment location facing north, east, south, and west. These four readings are averaged to determine canopy cover at the site. Canopy cover is determined during quarterly field accuracy checks.

7.5 Data Download

Data from the logger is downloaded as described in the instrument SOP, attached as Appendix B, on a quarterly basis: in March, June, September and December.

7.6 Logger Deployment and Field Activity Flowchart

Personnel responsible for implementing the Continuous Temperature Monitoring Program will follow the deployment, operation, and maintenance steps. Detailed instructions are provided in the section referred, and in decision trees attached as Appendix F.

1. Prior to logger deployment in the field, verify logger accuracy using two-point accuracy check (Section 8.2).
2. Field deployment:
    - c. Prepare loggers for deployment (Section 7.3).
    - d. Program loggers to take measurement every 30 minutes (Appendix B).
    - e. Deploy loggers in the field (Section 7.4).

3. Prepare for field QA/QC activities conducted on a quarterly basis (September, December, March, June):
    a. Prepare independent temperature probe to act as reference temperature probe in the field by conducting accuracy check (Section 8.3.2).
    b. OR take non-toxic, non-mercury NIST-traceable reference thermometer into the field to conduct QA/QC activities. If a reference thermometer is used, disregard procedures related to reference temperature probe error in the remainder of this decision tree.
4. In the field during quarterly accuracy check:
    a. Observe and record logger deployment: is logger fouled, buried in sediment, or dewatered?
    b. Download data (Appendix B).
    c. Field accuracy checks (Section 8.3.3):
        - Net sensor drift for the end of the previous logging quarter.
        - Sensor error caused by fouling.
        - Sensor error caused by calibration drift.
    d. Calculate total sensor error (Section 8.3.3).
        - Sum absolute value of reference temperature probe error, sensor error due to fouling, and sensor error due to calibration drift.
        - If acceptance criterion exceeded, correct data by reference temperature probe error and sensor error due to calibration drift (if needed) (Section 8.3.4).
    e. Redeploy logger.
    f. Determine canopy cover using a spherical densiometer.
5. Annually (September) verify logger accuracy using two-point accuracy check (Section 8.2 and 8.4).
6. Data management:
    a. Remove measurements prior to deployment and after removal of logger from the site to eliminate any air temperature measurements.
    b. Remove measurements within 1-hour of deployment to eliminate any water temperature measurements before equilibration.
    c. Visually check data for data errors or data gaps.
    d. Use summary statistics and automated checks to screen for data errors.
    e. Remedy any data errors or suspect data on a case-by-case basis:
        - Leave as is.
        - Exclude from data analysis.

        - Modify or adjust by constant factor or interpolation (Section 9.3, Table 9.1).

    f. Ensure that data are identified with the appropriate qualifier (Section 9.8.2).

7. Summary Statistics:
    a. 7-day average of the daily maximum value (7DADM) calculated for all freshwater sites.
    b. 1-day maximum value calculated for all marine sites.
8. Reports:
    a. As part of the Annual Water Quality Assessment Report, summary statistics will be compared with Lummi Nation Water Quality Standards.

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8. QUALITY ASSURANCE AND QUALITY CONTROL REQUIREMENTS (B5)

Quality Assurance and Quality Control (QA/QC) procedures include logger calibration, annual two-point accuracy check in the lab, and quarterly field accuracy checks.

8.1 Logger Calibration

The continuous temperature loggers will be calibrated by the manufacturer prior to deployment, and as needed per the manufacturer's specifications or as outlined in the equipment SOP (see Appendix B). If accuracy check checks fail to meet the acceptance criteria and corrective measures do not solve the problem, the logger will be returned to the manufacturer for recalibration or replacement. The minimum logger recalibration or replacement schedule is listed in Appendix B, the SOP for the continuous temperature loggers.

8.2 Accuracy Check – Prior to Initial Deployment

Prior to deployment of the continuous temperature loggers, a two-point accuracy check will be conducted in the laboratory. The two-point accuracy check involves comparison of the logger's temperature reading to the temperature reading of a National Institute of Standards and Technology (NIST) traceable thermometer using two water baths: ice water and room temperature water. The acceptance criterion for the accuracy check is ±0.2°C.

8.2.1 Two-Point Accuracy Check Methods

Equipment:

- Two ice chests or insulated containers
- Ice
- Reference thermometer that meets requirements listed in Section 8.7
- Data loggers to be accuracy checked

The ice water bath prepared as follows:

1. Program temperature loggers to collect temperature measurement at 15 second intervals (see Appendix B).
2. Fill an ice chest 1/3-1/2 full of ice.
3. Place continuous temperature loggers in ice and cover with additional ice.
4. Add water to the ice chest until even with the top of the ice.

5. Place NIST-traceable reference thermometer in ice bath and let stand 15 minutes for equilibration. **NOTE:** Agitate bath gently during equilibration and during temperature readings to avoid temperature stratification.[4]
6. Record ten temperature readings at one-minute intervals.
7. Remove temperature loggers and download data.
8. Calculate difference in readings between reference thermometer and temperature logger. Calculate mean difference in readings to determine accuracy/bias. Calculate standard deviation of logger readings to determine precision.

The room-temperature water bath should be prepared as follows:

1. Fill an ice chest or other insulated container with water and let sit overnight to reach room temperature.
2. Stir bath gently for five minutes prior to placing loggers and reference thermometer in the bath, during equilibration, and during temperature readings to avoid temperature stratification.[3]
3. Program temperature loggers to collect temperature measurement at 15 second intervals.
4. Place continuous temperature loggers and NIST-traceable reference thermometer in water. Let stand 15 minutes for equilibration. **NOTE:** Agitate bath gently during equilibration and during temperature readings to avoid temperature stratification.[4]
5. Record ten temperature readings at one-minute intervals.
6. Remove temperature loggers and download data.
7. Calculate difference in readings between reference thermometer and temperature logger. Calculate mean difference in readings to determine accuracy/bias. Calculate standard deviation of logger readings to determine precision.

Notes to keep in mind:

- Do not allow the temperature loggers or reference thermometer to touch the sides of the bath.
- Keep the bulb of the reference thermometer and the temperature sensor of the logger at the same level in the water. If multiple temperature loggers are checked at once, they can be bundled together for convenience.
- Agitating the baths continuously is required. It takes only 1-2 minutes for a bath to develop thermal stratification (Schuett-Hames et al. 1999).[4]

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[4] Agitation of the bath can be accomplished using manual, gentle stirring or a device that will circulate or agitate the water, including an air circulator (such as is used in a fish tank).

The acceptance criterion for the accuracy check is ±0.2°C. If an accuracy check reveals the mean difference between the reference temperature and the measured temperature is greater than 0.2°C, redo the two-point accuracy check using best practices (see Table 8.1 and Section 8.6). If logger accuracy exceeds the acceptance criterion, the logger is returned to the manufacturer for recalibration or replacement.

8.3 Accuracy Check – Field

A field accuracy check will take place quarterly in December, March, June, and September. The field accuracy check involves comparison of the temperature measurement taken by the continuous temperature logger to measurements taken by a reference temperature probe. Two types of error will be checked during the field accuracy check: sensor error caused by fouling and sensor error caused by calibration drift.

8.3.1 Equipment

For a quarterly accuracy check in the field, either of the following pieces of equipment may be used: option 1) a reference temperature probe that meets the acceptance criterion for an accuracy check against a NIST-traceable reference thermometer; or option 2) a non-toxic, non-mercury, NIST-traceable reference thermometer that meets the criteria listed in Section 8.7. A mercury or other toxic reference thermometer may not be used in the field due to risk of breakage and release of toxic substances into the environment. If option 1 is used, the steps listed in Section 8.3.2 must be followed; if option 2 is used, Section 8.3.2 may be skipped and "Error of the reference temperature probe" can be ignored in the calculation of total sensor error and analysis of error caused by fouling or calibration drift.

8.3.2 In the lab: accuracy check of reference temperature probe

Prepare an independent temperature probe to serve as the reference temperature probe in the field if a non-toxic, non-mercury NIST-traceable reference thermometer is not available. Verify the accuracy of the reference probe by comparing the temperature reading of the reference probe to the temperature reading of the lab reference thermometer (known temperature). The lab reference thermometer must meet the requirements listed in Section 8.7. Ensure that the water used for the accuracy check is thoroughly mixed (*i.e.,* is not thermally stratified) by agitating the water every 30 seconds, and keep the bulb of the reference thermometer at the same level as the sensor on the probe. After allowing the reference thermometer and probe to equilibrate, collect ten readings at 30-second intervals, the temperature reading from the reference thermometer and temperature reading from the probe. Calculate the difference in temporally paired readings from the reference thermometer and probe, and calculate the mean difference. This is the <u>error of the reference temperature probe</u>.

The acceptance criterion for the reference temperature probe is ±0.2°C.

If the mean difference in temperature reading between the reference thermometer and the independent temperature probe is greater than ±0.2°C, repeat the accuracy check using best practices (see Table 8.1 and Section 8.6). If the accuracy check does not meet the acceptance criterion after corrective actions have been taken, do not use the probe as a reference temperature probe in the field. Select another probe to use for this purpose, and repeat the accuracy check steps on the new probe.

Alternatively, a non-toxic, non-mercury, NIST-traceable reference thermometer that meets the criteria listed in Section 8.7 can be taken into the field for the field accuracy checks.

Datasheets have been set up in Excel to allow for automatic calculation of error. Field personnel are encouraged to use the Excel datasheets to facilitate error calculation and reduce human error.

8.3.3 In the field: sensor error caused by fouling and calibration drift

After retrieving the logger from the deployment location, noting any fouling on the field datasheet, and downloading the continuous temperature data from the logger, the logger is checked for sensor error caused by fouling and sensor error caused by calibration drift. This will involve comparison of the temperature measurements taken by the continuous temperature logger prior to cleaning and after cleaning (for sensor error caused by fouling) and comparison of the temperature measurement taken by the continuous temperature logger to measurements taken by a reference temperature probe (for error caused by calibration drift) (Wagner 2006).

Detailed methods for this error determination are listed below:

1. After downloading the temperature data from the logger, reprogram the logger to record a temperature measurement every 15 seconds (see Appendix B).
2. Return the logger into the water. Place the reference temperature probe into the water near, but not touching, the logger. Allow the logger and reference probe to equilibrate for a few minutes.
3. Take temperature readings at 30-second intervals for five minutes, recording the time (including seconds) of the measurement and the temperature reading of the reference probe.
4. Remove the logger from the water, and download the temperature data.
5. Calculate the difference in temporally paired readings between the reference probe and temperature logger. Calculate mean difference in readings. This is the net sensor drift for the end of the previous logging quarter.
6. Calculate the mean logger readings for the five minute interval. This is the initial mean logger temperature reading, which will be used in step 12.

7. Note any fouling of the logger. Clean the logger in warm water. Use mild dishwashing detergent if necessary.
8. Return the logger into the water. Place the reference temperature probe into the water near, but not touching, the logger. Allow the logger and reference probe to equilibrate for a few minutes.
9. Take temperature readings in 30-second intervals for five minutes, recording the time (including seconds) of the measurement and the temperature reading of the reference probe.
10. Remove the logger from the water, and download the temperature data.
11. Calculate the mean logger readings for the five minute interval. This is the post-cleaning mean logger temperature reading.
12. Calculate the difference between the initial mean logger temperature reading calculated in step 6 (prior to cleaning the logger) and the post-cleaning mean logger temperature reading calculated in step 11 (after cleaning the logger). This is the <u>sensor error caused by fouling</u>.
13. Calculate the difference in temporally paired readings between the reference thermometer and the cleaned temperature logger. Calculate mean difference in readings. This is the <u>sensor error caused by calibration drift</u>.

    <u>NOTE:</u> If the conditions are rapidly changing during the accuracy check, collect water in a 5-gallon bucket and use this water for conducting temperature accuracy check.

The acceptance criterion is ±0.5°C.

To calculate total sensor error for the field accuracy check, sum the absolute value of:

- Error of the reference temperature probe[5]
- Sensor error due to fouling (calculated in step 12)
- Sensor error due to calibration drift (calculated in step 13)

If the total error exceeds 0.5°C, a data correction must be applied to the previous collection period to reduce the error to within the acceptance criterion. See Section 8.3.4 for details on data correction in the field.

If the sensor error caused by calibration drift (calculated in step 13) alone exceeds the acceptance criterion (±0.5°C), the temperature logger must be returned to the lab for a two-point accuracy check and potentially returned to the manufacturer for recalibration before redeployment and/or replaced by a new, accuracy-checked logger.

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[5] Omit "Error of the reference temperature probe" if NIST-traceable reference thermometer used instead of an independent field temperature probe (*i.e.,* option 2 in Section 8.3.1).

Datasheets have been set up in Excel to allow for automatic calculation of error. Field personnel are encouraged to use the Excel datasheets to facilitate error calculation and reduce human error.

8.3.4 Data correction in the field

If field accuracy check reveals total sensor error exceeds the acceptance criterion of ±0.5°C, the accuracy check data should be corrected as follows:

- Adjust reference temperature probe readings by the reference temperature probe error. Recalculate sensor error caused by calibration drift and total sensor error.
- Adjust logger readings by the sensor error caused by calibration drift. Recalculate sensor error caused by calibration drift and total sensor error.
- If any additional data corrections are needed, note in Excel datasheet. These corrections should not be applied in the field.

Note that if total sensor error exceeds the acceptance criterion even after data corrections, it may not be necessary to return the logger to the lab for a two-point accuracy check and/or returned to the manufacturer for recalibration or replacement. Sensor error caused by calibration drift and sensor error caused by fouling can be corrected for when total sensor error exceeds the acceptance criterion (see Section 9.3).

8.4 Accuracy Check – Annual Lab Check

Annually, in September, the temperature loggers will be removed from the field and returned to the laboratory for accuracy check against a NIST-traceable reference thermometer. A replacement temperature logger will be deployed at the site to maintain continuous data collection following the methods previously described. After field accuracy check and determination of sensor error caused by fouling and calibration drift, a two-point accuracy check will be performed in the lab following the methods described in Section 8.2.

The two-point accuracy check should also be performed in the lab when sensor error caused by calibration drift exceeds ±0.5°C or if highly variable calibration drift is suspected.

8.5 Additional Accuracy Checks

After a temperature logger data download, results will be compared to temperature readings collected from the site during regular water quality monitoring (Lummi Nation Ambient Surface Water Quality Monitoring Program). Summary statistics will be calculated to inform potential changes and improvements to logger deployment location and overall representativeness of sites selected for monitoring programs.

8.6 Acceptance Criteria and Corrective Actions

Table 8.1 summarizes the acceptance criteria for various QA/QC steps, as well as instructions for corrective actions in the event that acceptance criteria are not met.

Table 8.1 Acceptance Criteria and Corrective Actions

Quality Assurance Step	Acceptance Criteria	What to do if acceptance criteria are not met
Pre-deployment accuracy check	±0.2°C	Carefully redo accuracy check. Ensure timing of record collection for the reference thermometer and logger match (note daylight savings time), the water is not stratified, and reference thermometer and logger are not touching the sides of the container. Ensure the bulb of the thermometer and temperature sensor of the logger are at the same level in the water and that sufficient time is allowed for equilibration. If still doesn't meet acceptance criterion, send logger back to manufacturer for recalibration or replacement.
Accuracy check of reference temperature probe (if used)	±0.2°C	Carefully redo accuracy check. Ensure water is not stratified and the reference thermometer and probe are not touching the sides of the container. Ensure the bulb of the thermometer and the temperature sensor of the probe are at the same level in the water and that sufficient time is allowed for equilibration. If still doesn't meet acceptance criterion, use another independent temperature probe to serve as the reference probe in the field.
Field accuracy check Sum of absolute value of the reference temperature probe error, fouling error and calibration drift error **Note:** omit reference temperature probe error if NIST-certified reference thermometer used instead of an independent field temperature probe	±0.5°C	Correct reference temperature probe readings by reference temperature probe error; recalculate error. Correct logger readings by sensor error caused by calibration drift; recalculate error. If data correction(s) decreases recalculated total sensor error to below ±0.5°C, note that these data must be labeled "corrected" in the database and the data corrections are needed. If correction(s) do not decrease error to below ±0.5°C, data must be marked suspect as needing further review and correction. If error caused by calibration drift alone exceeds the acceptance criterion of ±0.5°C or highly variable calibration drift is suspected, the logger is returned to the lab for a two-point accuracy check and potentially returned to the manufacturer for

Table 8.1 Acceptance Criteria and Corrective Actions

Quality Assurance Step	Acceptance Criteria	What to do if acceptance criteria are not met
		recalibration or replacement. See Section 9.3 for details on data correction.
Annual lab accuracy check	±0.2°C	Carefully redo accuracy check. Ensure that timing of record collection for the reference thermometer and logger match (note daylight saving time), the water is not stratified, and the reference thermometer and logger are not touching the sides of the container. Ensure the bulb of the thermometer and the temperature sensor of the logger are at the same level in the water, and that sufficient time is allowed for equilibration. If still doesn't meet acceptance criterion, send logger back to manufacturer for recalibration or replacement.

8.7 Requirements of the Reference Thermometer

The reference thermometer used to verify acceptable accuracy of the temperature loggers must meet one of the following criteria:

- NIST-certified,
- Manufacturer-certified as NIST-traceable and carry a current NIST certification, or
- NIST-traceable certification that is no more than 2 years old or still current according to the manufacturer.

In the event that a reference thermometer meeting the required criteria is not available, a secondary standard for the reference thermometer is as follows: NIST-traceable certificate of calibration with expiration date no greater than 5 years prior. The reference thermometer must remain within ±0.2°C of 0°C in ice water bath. Note the use of a reference thermometer meeting the secondary standard in the field datasheets and database.

8.8 Corrective Actions

Table 8.2 summarizes potential problems that may be encountered in deploying the temperature loggers, downloading data, or conducting QA/QC activities. Corrective actions are suggested for various potential problems.

Table 8.2 Troubleshooting and Corrective Actions for Potential Problems

Potential Problem	Corrective Action
Dirty sensor	Clean sensor
Poor connections at monitor or sensor	Tighten connections
Failure in electronics	Replace sensor or monitor
Logger buried or dewatered	To prevent future burial or dewatering, redeploy logger in a location with sufficient water at low flow conditions. Attach logger to a custom block to keep it above the sediment, if practicable.
Logger cleaned before obtaining pre-cleaning accuracy check comparison	Estimate error as sum of absolute values of reference temperature probe error and calibration drift. Flag the logger data as unknown sensor error due to fouling.
Cannot calculate sensor error caused by fouling or sensor error caused by calibration drift (*e.g.,* technical difficulties prevent post-cleaning accuracy check comparison)	Estimate error as sum of absolute values of reference temperature probe error and net sensor drift for the end of the previous logging quarter (step 5 in Section 8.3.3).
Logger is excessively dirty (*i.e.,* sensor error caused by fouling consistently exceeds ±0.5°C acceptance criterion during field accuracy checks)	Temperature data will need to be adjusted to correct for sensor error due to fouling (see Section 9.3). Consider changing the logger deployment location to an area that may reduce fouling. Consider downloading data from this logger more frequently to reduce fouling error at the time of data download.
Sensor error caused by calibration drift appears to be highly variable or exceeds ±0.5°C	Return the logger to the lab for a two-point accuracy check. If needed, return to manufacturer for recalibration or replacement.
Logger does not meet QA/QC acceptance criteria	See Section 8.5, Table 8.1.
Rapidly changing conditions during field accuracy check	If the conditions are rapidly changing during the field accuracy check, collect water in a 5-gallon bucket and use this water for conducting pre- and post-cleaning accuracy checks.

8.9 Equipment Maintenance (B6) and Calibration (B7)

Information regarding maintenance of the temperature loggers is provided in the instrument SOP, attached as Appendix B.

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9. DATA MANAGEMENT (B10)

As previously described, data will be downloaded from the continuous temperature monitoring loggers in the field as specified in the instrument SOP (see Appendix B). A backup of the data will be saved prior to clearing the memory of the logger and reprogramming for mid-deployment QA/QC checks. The data will be saved on a field laptop and transferred to secure LIBC servers upon return to the office from the field. Data saved on the LIBC servers are backed up regularly. Data will be screened, data errors identified, and data corrected as needed prior to upload to the continuous temperature monitoring database with appropriate metadata. Data are generally only entered into the database if method and quality control activity criteria are met, however data that have been corrected or otherwise modified will be labeled as such in the database. Continuous temperature monitoring data will also be transmitted to the EPA for inclusion in the STORET Data Warehouse via upload to the Water Quality Exchange (WQX) upon approval by the Water Resources Manager and the Deputy Director.

The Water Resources Specialist I will be responsible for data management of continuous temperature monitoring data with support and supervision provided by the Water Resources Specialist II and the Database Manager.

9.1 QA/QC Data

Both QA/QC data and continuous temperature data for each logger and site are accessible in the database. Data are checked against quality control activity data and are rated (validated) according to their quality:

- Data with poor QA/QC performance are prominently labeled as rejected in the database and dually rated with the implementation of the data validation protocol. Suspect data are rated as originally being suspect and may have other qualifiers assigned during the rating process based on data quality.
- Where data are not recorded electronically in the database, it is noted on the accuracy check record and field datasheets that measurements were made but the results were too inaccurate, imprecise, or un-traceable for inclusion in the database.
- Until the data have been reviewed and assessed as described above, including for transcription errors, the data are prominently marked as “Draft” and “Preliminary, Subject to Revisions.”

9.2 Data Screening and Identification of Data Errors

Prior to inclusion in the database, data are screened for errors based on time, visual checks, and summary statistics.

Pre- and post-deployment observations are removed. Using field notes or datasheets listing the exact time loggers were deployed and recovered, temperature measurements logged prior to deployment and after recovery are removed from the dataset to eliminate possible air temperature measurements. A one-hour buffer period is also applied; observations within the first hour after deployment are removed to ensure that the logger temperature readings have stabilized and to eliminate any air temperatures that may have been collected.

Data are corrected based on results of quarterly field accuracy checks. If field accuracy check data were adjusted by sensor error caused by calibration drift, data for that quarter are corrected for calibration drift by a constant correction factor, if sensor error caused by calibration drift remained steady since the previous accuracy check, or using a linearly interpolated correction factor, if sensor error caused by calibration drift did not remain steady.

If the field accuracy check did not meet the acceptance criterion after data adjustment by calibration drift, data for that quarter are corrected for sensor error caused by fouling. Fouling error can be caused by a single event or gradually over time by visual examination of temperature data graphed over time.

Details on data correction are provided in Section 9.3.

Data will be checked visually and by trend analysis to determine if data errors have taken place or if data gaps are present. The following visual checks will be performed to screen for data errors (EPA 2014):

- Individual data points are plotted by time to check for missing data or abnormalities.
- Water and air temperature are graphically compared. A close correspondence between water and air temperature strongly indicates that the logger was dewatered for that period of time.
- Time permitting; data across years are graphically compared. If data from one year are dramatically different, data errors may be present.

Summary statistics and automated checks are also used to screen for data errors. These include (EPA 2014):

- Calculation of upper and lower 5th percentiles.
- Flagging of data points as suspect if they:
    - Exceed a maximum of 25°C
    - Exceed a minimum of -1°C
    - Exceed a daily change of 10°C
    - Exceed the upper 5th percentile of the overall distribution
    - Fall below the lower 5th percentile of the overall distribution

If data are flagged as suspect, potential errors are investigated and addressed on a case-by-case basis. Suspect data points are cross-checked with air temperatures to determine whether the logger was dewatered during this period.

9.3 Data Correction

After data gaps or errors have been identified, data will be corrected, removed, or left as is on a case-by-case basis. Errors identified during logger deployment, accuracy check, and fouling check can also be corrected prior to data analysis.

In general, data can be corrected by applying a constant correction factor or by linearly interpolating a correction factor. A constant correction factor is applied if sensor error caused by calibration drift remained steady for the entire logging quarter (*i.e.,* calibration error for beginning of logging quarter is compared to calibration error for the end of the logging quarter). A linearly interpolated correction factor is used if a gradual change in either sensor error caused by calibration drift or sensor error caused by fouling has occurred. The correction factor is linearly interpolated from deployment start (*e.g.,* minimum correction) to deployment end (*e.g.,* maximum correction) and the appropriate correction factor is applied to each data point based on time. The correction factor can be either a percentage or integer. A percentage correction factor is recommended as it reduces the occurrence of negative temperature values (Wagner et al. 2006).

Correction factors can also be applied to correct for fouling caused by a single event, if evidenced by a visual inspection of temperature data across time. In this case, a constant correction factor is only applied to the period of time after which the fouling took place (*i.e.,* the correction factor is not applied to the period of time prior to the fouling event).

Table 9.1 Data Correction Actions

Problem	Action
Missing data	Leave blank.
Logger was dewatered or buried in sediment for part of the deployment period	Determine the period during which the problem occurred and exclude these data from the analysis.
Recorded values are off by a constant, known amount	Adjust each recorded value by a single constant value within the correction period. For example: constant calibration drift (see Sections 8.2 and 8.4).
A large amount of drift is present, and mid-deployment accuracy check acceptance criterion is not met even after data correction (*e.g.,* of reference temperature probe error and constant calibration drift). It is unknown when and by how much the logger readings have drifted (*e.g.,* by fouling or non-constant calibration drift).	Adjust each recorded value by any constant, known amounts (*e.g.,* constant calibration drift). Determine whether drift occurred gradually over time or after an event by visually examining temperature data graphed over time. If gradual drift, linearly interpolate correction factor from deployment start (*e.g.,* zero correction)

Table 9.1 Data Correction Actions

Problem	Action
	to deployment end (*e.g.,* maximum correction) and apply appropriate correction factor based on time. This can be done as a percentage or integer. Percentage is recommended as it reduces the occurrence of negative temperature values (Wagner et al. 2006).

9.4 Summary Statistics

Only verified or corrected data will be used to calculate summary statistics. Suspect or excluded data will not be used in calculation of summary statistics. The seven-day average of the daily maximum value (7DADM) is calculated for all freshwater sites. A daily maximum value is calculated for all marine sites.

9.5 Assessments, Oversight and Response Actions (C1)

Section 2 lists the key personnel and their responsibilities. In summary, the person conducting the monitoring (primarily the Water Resources Specialist I, but also the Water Resources Specialist II and Water Resources Technician III) is responsible for performing all inspections, accuracy checks, and quality control activities. The Water Resources Specialist I and the Water Resources Specialist II are responsible for screening the data and applying correction factors as necessary, with support from the Database Manager. The Database Manager is responsible for transmitting the data to STORET. The Water Resources Technician III reports to the Water Resources Specialist I, who in turn reports to the Water Resources Specialist II. The Water Resources Specialist II and the Database Manager report to the Water Resources Manager, who ensures that QA/QC objectives and reporting requirements are achieved.

Operator error and equipment problems detected during accuracy check and other QA/QC activities will initiate actions to correct the problem. If accuracy cannot be verified to be within the QA/QC acceptance criteria, a new logger that meets QA/QC will be deployed at the site and the malfunctioning logger will be returned to the manufacturer for recalibration or replacement. QA/QC activities also inform potential data correction factors that may be applied, as appropriate.

9.6 Reports to Management (C2)

The Water Resources Specialist I and Specialist II are responsible for evaluating monitoring and quality control data and reporting to the Water Resources Manager regularly and as needed if problems are detected. The Water Resources Specialist II performs periodic Quality Assurance audits that the Water Resources Manager evaluates for compliance with the project goals.

When problems are detected and not resolved through standard practices or are of a larger nature than the staff conducting water quality sampling typically address, the Water Resources Specialist I, Water Resources Specialist II, and the Water Resources Manager will jointly develop an action plan to remedy the problem with clear roles, responsibilities, and timelines.

The Water Resources Specialist I prepares an annual Water Quality Assessment Report that summarizes the collected water and air temperature data, compares the results with the Lummi Nation water quality standards and the data for the period of record, and documents attainment or non-attainment of designated uses. These reports are reviewed and approved by the Water Resources Manager and the Deputy Director, and the approved reports are transmitted to the EPA by March 31st annually. The Water Resources Manager submits semi-annual (twice per year) progress reports to the EPA Project Officer that describe program status, problems, remedies, and schedules.

9.7 External Data Acquisition (B9)

Although no external data acquisition is currently planned, data from the U.S. Geological Survey (USGS) gage station on the Nooksack River at Ferndale (USGS 12213100) may be acquired and compared with temperature data collected at site SW118 (Nooksack River at Marine Drive). Daily maximum, minimum and average temperature data for the Nooksack River gage station will be downloaded from the USGS website, if used. Any external data used will be clearly marked as such and will include any metadata available.

Continuous temperature data collected by other LNR departments (*e.g.,* Restoration Division) may be used to supplement the data collected under this QAPP. If the temperature data were collected following an approved QAPP, these data may be used in addition to the data collected under this QAPP to determine whether waters meet the Surface Water Quality Standards. All data external to the program detailed in this QAPP will be clearly marked as such and will include any metadata available.

9.8 Data Review and Usability

9.8.1 Data Review, Verification, and Validation Requirements (D1)

The QA/QC acceptance criterion of ±0.5°C must be met in order for data to be validated. Data that are not validated due to QA/QC acceptance criteria not being met can be used if data are corrected or modified in order to meet QA/QC.

Details on the data review, verification and modification process are listed in Sections 9.2 and 9.3.

9.8.2 Verification and Validation Methods (D2)

As previously described, water temperature data are generally only entered into the database if method and quality control activity criteria are met. Data that have been corrected or otherwise modified will be marked appropriately in the database, and all relevant metadata included. If data are entered into the database that do not meet the method and quality control activity criteria or are otherwise suspect, the data are clearly labeled as suspect along with the reason in the database. Suspect data are reviewed for inclusion in calculations, and rated (validated) in the database on a case-by-case basis.

Data qualifiers include:

- "Verified" for data that meet QA/QC requirements without correction factors.
- "Corrected" for data that have been modified using correction factors, either by adding an integer or applying a percentage modification.
- "Removed" for data that have been removed from analysis. Potential reasons for removal include: measurement taken outside of deployment period, measurement taken while logger dewatered or buried in sediment, or excessive error did not meet QA/QC acceptance criterion and data could not be adjusted to account for error.
- "Suspect" for data that do not meet the method and quality control activity criteria or are otherwise suspect. Reason for suspicion should be listed in the database.

The Database Manager, Water Resources Specialist II, Water Resources Specialist I, and Water Resources Technician III are responsible for verifying and validating project data and information. The Water Resources Specialist I is responsible for ensuring all QA/QC protocols are followed, and for quantifying or qualifying data quality to data users. When problems are detected and not resolved through standard practices or are of a larger nature than the staff conducting water quality sampling typically address, the Water Resources Specialist I, Water Resources Specialist II, and the Water Resources Manager will jointly develop an action plan to remedy the problem with clear roles, responsibilities, and timelines.

Standard forms used for data entry are attached as Appendix E.

9.8.3 Reconciliation with User Requirements (D3)

Verified data are validated using the grading system described in Section 9.8.2 to indicate a level of data modification and data quality. All data are stored with appropriate metadata. In general, the uncertainty of the validated data is ±0.5°C due to acceptance criteria for QA/QC activities.

Since 2009, continuous temperature monitoring data have been collected for informational purposes prior to the development of this QAPP. As no written and approved QA/QC procedures were in place at the time of the previous data collection, the previous data will not be included in summary reports of the data collected for the Continuous Temperature Monitoring Program as outlined in this QAPP. If previously collected data are used for comparison, these data will be clearly marked as "suspect" or otherwise delineated that they were collected without a written and approved QAPP. Previously collected data will not be used for any decisions leading from data collected under the Continuous Temperature Monitoring Program as outlined in this QAPP.

The Continuous Temperature Monitoring Program is an ongoing program and is not designed to prove or disprove specific hypotheses.

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11. ACRONYMS AND ABBREVIATIONS

7DADM	7-Day Average of the Daily Maximum
EPA	Environmental Protection Agency
LIBC	Lummi Indian Business Council
LNR	Lummi Nation Natural Resources Department
LWRD	Lummi Nation Natural Resources Department, Water Resources Division
NIST	National Institute of Standards and Technology
QAPP	Quality Assurance Project Plan
CWRMP	Comprehensive Water Resources Management Program
CFS	Cubic Feet Per Second
QA/QC	Quality Assurance/Quality Control
USGS	U.S. Geological Survey

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12. APPENDICES

Appendix A. Equipment/Instrument Manual for HOBO Water Temp Pro v2 (U22-001)

Appendix B. Standard Operating Procedures for HOBO Water Temp Pro v2 (U22-001)

Appendix C. Protective Housing for Continuous Temperature Loggers

Appendix D. Rebar, Cable and L-Shaped Block Deployment Technique Schematics

Appendix E. Data Sheets for Lab and Field Accuracy Checks

Note that these data sheets should be filled in using Microsoft Excel in order to make use of the built-in calculation of error. Required calculations are listed on the data sheets in the event that data sheets are printed out and filled in by hand in the field.

Appendix F. Decision Trees

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Appendix A. Equipment/Instrument Manual for HOBO Water Temp Pro v2 (U22-001)

HOBO® Water Temp Pro v2 (U22-001) Manual

The HOBO Water Temp Pro v2 logger is designed with a durable, streamlined, UV-stable case for extended deployments measuring temperature in fresh or salt water. The small size of the logger allows it to be easily mounted and/or hidden in the field. It is waterproof up to 120 m (400 feet) and rugged enough to withstand years of use, even in stream conditions. It has enough memory to record over 42,000 12-bit temperature measurements.

The logger uses an optical USB communications interface for launching and reading out the logger. The optical interface allows the logger to be offloaded without compromising the integrity of the seals. The USB compatibility allows for easy setup and fast downloads.

HOBO Water Temp Pro v2

U22-001

Included Item:

- Communications window protective cap

Required Items:

- Coupler (COUPLER-C) and USB Optic Base Station (BASE-U-4) *or* HOBO Waterproof Shuttle (U-DTW-1)
- HOBOware®

Accessories:

- Protective boot; black (BOOT-BLK) or white (BOOT-WHT)
- Replacement communications window protective caps (U22-U24-CAP)

Specifications

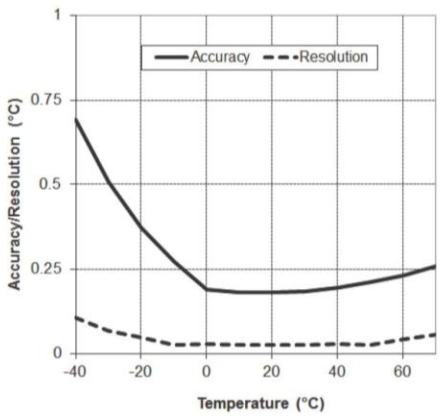
Temperature Sensor

Operation Range	-40° to 70°C (-40° to 158°F) in air; maximum sustained temperature of 50°C (122°F) in water
Accuracy	±0.21°C from 0° to 50°C (±0.38°F from 32° to 122°F), see Plot A
Resolution	0.02°C at 25°C (0.04°F at 77°F), see Plot A
Response Time (90%)	5 minutes in water; 12 minutes in air moving 2 m/sec (typical)
Stability (Drift)	0.1°C (0.18°F) per year

Logger

Real-time Clock	± 1 minute per month 0° to 50°C (32° to 122°F)
Battery	2/3 AA, 3.6 Volt Lithium, factory-replaceable ONLY
Battery Life (Typical Use)	6 years with 1 minute or greater logging interval
Memory (Non-volatile)	64K bytes memory (approx. 42,000 12-bit temperature measurements)
Weight	42 g (1.5 oz)
Dimensions	3.0 cm (1.19 in.) maximum diameter, 11.4 cm (4.5 in.) length; mounting hole 6.3 mm (0.25 inches) diameter
Wetted Materials	Polypropylene case, EPDM o-rings, stainless steel retaining ring
Buoyancy (Fresh Water)	+13 g (0.5 oz.) in fresh water at 25°C (77°F); +17 g (0.6 oz.) with optional boot
Waterproof	To 120 m (400 ft.)
Shock/Drop	1.5 m (5 ft.) drop at 0°C to 70°C (32°F to 150°F)
Logging Interval	Fixed-rate or multiple logging intervals, with up to 8 user-defined logging intervals and durations; logging intervals from 1 second to 18 hours. Refer to the HOBOware software manual.
Launch Modes	Immediate start and delayed start
Offload Modes	Offload while logging; stop and offload
Battery Indication	Battery voltage can be viewed in status screen and optionally logged in datafile. Low battery indication in datafile.
NIST Certificate	Available for additional charge
CE	The CE Marking identifies this product as complying with all relevant directives in the European Union (EU).

Specifications (continued)

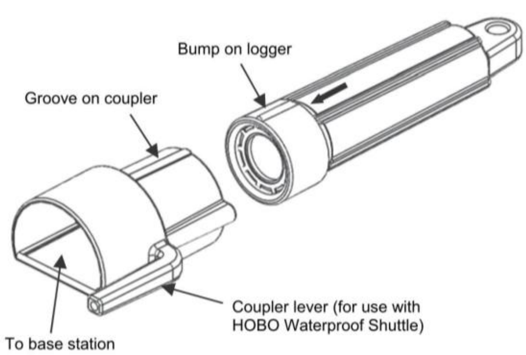


Plot A

Connecting the Logger

The HOBO Water Temp Pro v2 requires a coupler and USB Optic Base Station or HOBO Waterproof Shuttle to connect to the computer.

1. Install the logger software on your computer before proceeding.
2. Follow the instructions that came with your base station or shuttle to attach the base station or shuttle to a USB port on the computer.
3. Make sure the logger's communications window is clean and dry. (Use a clean, nonabrasive cloth, if necessary.) If the logger is wet, wipe off excess moisture.
4. Attach the coupler to the base station or shuttle, then insert the logger into the coupler so that the bump on the logger slides into the groove of the coupler. There is also an arrow etched on the logger case showing the direction the logger should be inserted into the coupler.



If you are using an older model of this logger and the arrow is not visible, hold the curved side of the coupler up as shown above. Insert the logger with the flat side up (the side in line with the flat side of the mounting hole).

5. If you are using the HOBO Waterproof Shuttle, briefly press the coupler lever to put the shuttle into base station mode.
6. If the logger has never been connected to the computer before, it may take a few seconds for the new hardware to be detected by the computer.
7. Use the logger software to launch the logger. You can check the logger's status, read out the logger while it continues to log, stop it manually with the software, or let it record data until the memory is full.

Refer to the software user's guide for complete details on launching, reading out, and viewing data from the logger, including multiple logging intervals.

Important: USB communications may not function properly at temperatures below 0°C (32°F) or above 50°C (122°F).

Note: The logger consumes significantly more power when it is "awake" and connected to a base station or shuttle. To conserve power, the logger will go into a low-power (sleep) mode if there has been no communication with your computer for 30 minutes. To wake up the logger, remove the logger from the coupler, wait a moment, then re-insert the logger.

Note: The first time you launch the logger, the deployment number will be greater than zero. Onset launches the loggers to test them prior to shipping.

Operation

A light (LED) in the communications window of the logger confirms logger operation. (In brightly lit areas, it may be necessary to shade the logger to see the LED blink.) The following table explains when the light blinks during logger operation:

When:	The Light Does this:
The logger is logging	Blinks once every one to four seconds (the shorter the logging interval, the faster the light blinks); blinks when logging a sample.
The logger is awaiting a start because it was launched in Start At Interval or Delayed Start mode	Blinks once every eight seconds until logging begins

Sample and Event Logging

The logger can record two types of data: samples and events. Samples are the sensor measurements recorded at each logging interval (for example, temperature every minute). Events are independent occurrences triggered by a logger activity, such as Bad Battery or Host Connected. Events help you determine what was happening while the logger was logging.

The logger stores 64K of data, and can record over 42,000 12-bit temperature measurements.

Deploying and Protecting the Logger

Follow these guidelines for deploying and protecting the logger:

Some monitoring applications require precise placement of the temperature sensor, such as measuring the temperature of a flow at the bottom of a stream or river. Ensure that the logger is appropriately secured so that the temperature sensor is in the desired measurement location.

Important: The plastic case will become brittle at temperatures lower than -20°C. If the logger is deployed in a location where the temperature drops below -20°C, make sure the logger remains stationary and is not pulled on or struck. Return the logger to above -20°C before handling.

- The opening at the sensor end of the logger accepts 1/4 inch (6.35mm) diameter nylon cord or other strong cable. If wire is wrapped through the sensor end to secure the logger, make sure the wire loop is snug to the sensor end. Any slack in the loop may cause excessive wear.
- The logger is slightly positive buoyant so that it will float if it is inadvertently dropped in the water or breaks free from its mooring. You may want to mark or label the logger with contact information in case the logger is lost.
- Use the included cap to protect the communications window in the logger from fouling and abrasion. Place the protective cap over the communications window before deploying the logger.
- As an alternative to the included protective cap, use the optional boot (Part # BOOT-BLK or BOOT-WHT) for high fouling environments and for protection against very cold temperatures (which can make the case brittle and prone to fracture) or repeated pounding and abrasion caused by turbulent flow. The boot slides over the logger, has a removable end cap, and is flexible enough to allow you to attach the coupler without removing the boot. To attach the base station, remove the end cap and firmly insert the logger until the boot folds back. Insert the logger into the coupler so that the bump on the logger slides into the groove of the coupler as shown on page 2.

  Although the boot does not cover the sensor end of the logger, the temperature response time (to 90% of final value) in water increases slightly from 5 to 8 minutes due to the increased mass.
- Depending on water conditions and desired measurement location, the logger should be appropriately weighted, secured, and protected.
- An alternative to the optional boot in high fouling environments is to protect the logger with plastic wrap that can be removed and replaced as needed.
- This logger should not be immersed for extended periods in any liquid other than fresh or salt water. To do so may void the warranty (refer to the Service and Support section). If you have any questions about chemical resistance, call Onset.
- Prolonged exposure to chlorinated water is not recommended.
- To clean the logger, rinse it in warm water. Use a mild dishwashing detergent if necessary. Do not use harsh chemicals, solvents, or abrasives, especially on the communications window.

Battery

The battery in the HOBO Water Temp Pro v2 is a 3.6 Volt lithium battery. The battery life of the logger should be about six years. Actual battery life is a function of the number of deployments, logging interval, and operation/storage temperature of the logger. To obtain a six-year battery life, a logging interval of one minute or greater should be used and the logger should be operated and stored at temperatures between 0° and 25°C (32° and 77°F). Frequent deployments with logging intervals of less than one minute, and continuous storage/operation at temperatures above 35°C, will result in significantly lower battery life. For example, continuous logging at a one-second logging interval will result in a battery life of approximately one month.

The logger can report and log its own battery voltage. If the battery falls below 3.1 V, the logger will record a "bad battery" event in the datafile. If the datafile contains "bad battery" events, or if logged battery voltage repeatedly falls below 3.3 V, the battery is failing and the logger should be returned to Onset for battery replacement.

To have your logger's battery replaced, contact Onset or your place of purchase for return arrangements. Do not open the case or attempt to replace the battery yourself. There are no user-serviceable parts inside. If you open the case, the warranty will be voided, and the logger may no longer be waterproof.

WARNING: Do not cut open, incinerate, heat above 100°C (212°F), or recharge the lithium battery. The battery may explode if the logger is exposed to extreme heat or conditions that could damage or destroy the battery case. Do not dispose of the logger or battery in fire. Do not expose the contents of the battery to water. Dispose of the battery according to local regulations for lithium batteries.

Appendix B. Standard Operating Procedures for HOBO Water Temp Pro v2 (U22-001)

This Standard Operating Procedure (SOP) provides details on the specifications, use, maintenance, and calibration of the HOBO Water Temp Pro v2 continuous temperature logger.

Instrument Specifications

Range, Accuracy, and Sensitivity/Readability

The specifications of the HOBO Water Temp Pro v2 are listed in the table below.

Table 12.1 Range, Accuracy, and Sensitivity/Readability of HOBO Water Temp Pro v2

Operation Range	Accuracy	Resolution	Stability/Drift
-40°C to 70°C in air Maximum 50°C in water	±0.21°C from 0-50°C	0.02°C at 25°C (approximately 0.02°C from 0-40°C)	0.1°C per year

Temperature Data Recording

The average battery use, memory and response time of the HOBO Water Temp Pro v2 are listed in the table below.

Table 12.2 Battery Life, Memory and Response Time of HOBO Water Temp Pro v2

Battery Life (Typical Use)	Memory	Response Time (90%)
6 years with 1 minute or greater logging interval	64K bytes memory (approximately 42,000 12-bit measurements; 9 months at measuring interval of 10 minutes, 28 months at measuring interval of 30 minutes)	5 minutes in water; 12 minutes in air moving 2 m/sec

Instrument Calibration

The loggers are calibrated by the manufacturer. If a logger does not meet quality control criteria, it will be sent back to the manufacturer for recalibration or replacement. At minimum, the loggers will be returned to the manufacturer for recalibration or replacement every two years.

Preparation for Deployment

The loggers will be deployed with a plastic cap covering the communications window for protection during deployment. The loggers will be housed in a protective PVC housing to prevent solar radiation (which can influence temperature measurements) or damage to the logger during deployment.

Logger Setup and Data Download

The logger must be connected to the shuttle in order to program the logger or to download data. Instructions for connecting the logger to the shuttle, setting up and launching the logger, and downloading data from the logger follow.

Connecting Logger to Shuttle

1. Connect the coupler for the Water Temp Pro v2 to the half circle end of the shuttle. Press firmly to ensure that the coupler is properly attached.
2. Connect the logger to the coupler with the logger's communications window toward the coupler opening so that the bump on the logger (marked with an arrow and "Comm. Alignment") slides into the groove on the coupler. Press firmly to ensure the logger is seated all the way in the coupler. Note that the logger's communications window should be clean and dry. It can be cleaned using a clean, nonabrasive cloth if necessary. Note also that the protective plastic cap should be removed from the communication window before connecting to the coupler.
3. Press the coupler lever briefly to initiate the communication between the computer, shuttle and logger. The yellow light will flash while communications are underway. The green light will flash when the connection is complete. The red light will flash if an error has occurred.

Data Download

The following steps should be followed when downloading data from the logger in the field:

1. Connect the logger to the shuttle following the steps in Connecting Logger to Shuttle section, above. The shuttle will automatically download any data on the logger onto the shuttle as long as the shuttle is not yet connected to the laptop.
2. Connect the HOBO Waterproof Shuttle (U-DTW-1) to the field laptop with a USB interface cable. Unscrew the center cap with retaining loop from the large cap to expose the USB port.

3. Open HOBOware Pro on the field laptop.
4. Select the icon for Readout Device (or go to Device > Readout). Select the device to communicate with – here it should show the logger information (HOBO U22-001 Water Temp, S/N XXX), not the shuttle.
5. If the logger is currently logging, you will be asked if you would like to stop logging before reading out the logger. Select Don't Stop to continue.
6. Save the file in the appropriate folder (Desktop/Jamie Mattson/HOBOware) based on the site to which the logger is deployed. Name the file using the convention: site number, underscore, start date of data collection (YYYYMMDD), underscore end date of data collection (YYYYMMDD). For example: SW011_20140131_20140630. The file will be saved as an Onset HOBO Datafile.
7. Change Plot Setup:
    a. Change temperature measurement units to °C
    b. Make sure "batt" is unchecked
    c. Under "Select Internal Loggers to Plot" click "None"
    d. Select OK
8. Save the file as a CSV file. Go to File > Export Points as Excel Text. Export Options window will open. Select "Export to a single file" and press "Export". You will need to save the file in the appropriate folder (Desktop/Jamie Mattson/HOBOware) based on the site to which the logger is deployed. Name the file using the convention: site number, underscore, start date of data collection (YYYYMMDD), underscore end date of data collection (YYYYMMDD). For example: SW011_20140131_20140630. The file will be saved as an Excel Comma Separated Values (CSV) file.

Programming and Launching the Logger

The logger will need to be programmed and launched for initial use and anytime the logging interval needs to be changed.

1. Connect the logger to the shuttle following the steps in Connecting Logger to Shuttle section, above.
2. Connect the HOBO Waterproof Shuttle (U-DTW-1) to the field laptop with a USB interface cable. Unscrew the center cap with retaining loop from the large cap to expose the USB port.
3. Open HOBOware Pro on the field laptop.
4. Select the icon for Launch Device (or go to Device > Launch). Select the device to communicate with – here it should show the logger information (HOBO U22-001 Water Temp, S/N XXX), not the shuttle.
5. If the logger is already logging, you will be warned that launching the logger will stop the logger first. Select Yes to continue.

6. If the logger has data that has not been read out, you will be warned that launching the logger will permanently erase any stored data on the logger. Download any data that needs to be saved from the logger before continuing, and select No and follow instructions in Data Download section. If data do not need to be saved, select Yes to continue.
7. The Logger Launch window will open. Provide a description, update the logging interval as needed, and select launch options (immediate launch, interval launch or delayed launch). Select Launch to continue. At the bottom of the screen, "Launch Successful" will be listed.

Troubleshooting

The table below lists potential solutions to issues that may arise in the use of the HOBO temperature logger.

Table 12.3 Issues and Potential Solutions

Issue	Potential Solution
Red light flashes – connection error between logger and shuttle	Make sure that the coupler is firmly connected to the shuttle by pressing the two parts firmly together against a hard surface. Make sure that the logger is properly oriented in the coupler (bump in the groove) and fully pushed into the coupler. Ensure that the magnet at the bottom of the coupler handle is present. Try with a different logger to determine if the problem is with the connection or with the logger.
HOBOware not recognizing that logger is connected	If HOBOware is not recognizing that the logger is connected to the shuttle (*i.e.,* the instrument type it recognizes is the shuttle, not the logger), make sure that the logger and the shuttle are in communication by pushing the lever on the side of the shuttle. You may need to shut down HOBOware and reopen.

See also the instrument manual (attached as Appendix A of the Continuous Temperature Monitoring QAPP) for additional details.

Appendix C. Protective Housing for Continuous Temperature Loggers

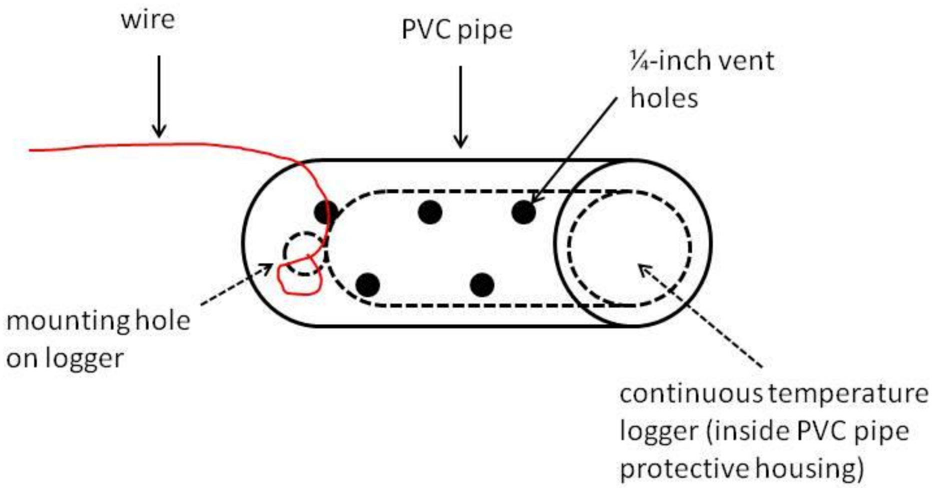


Figure 12.1 Schematic of continuous temperature logger in protective housing. Protective housing is made out of PVC pipe with ¼-inch vent holes. To secure the protective housing to the logger, pass a wire, cable, or ziptie through the vent holes and through the logger's mounting hole. To secure a logger to rebar, block, or buoy, a wire, cable, or ziptie can be threaded through the vent holes on the protective housing.

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Appendix D. Deployment Technique Schematics

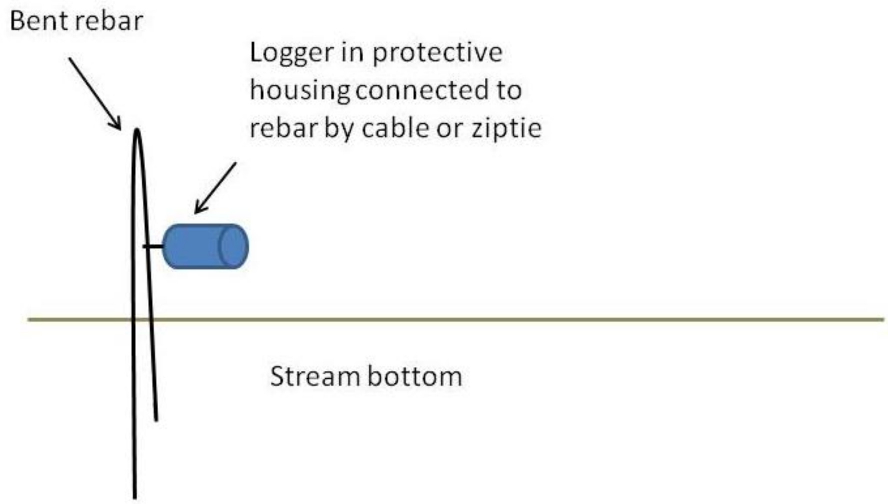

Figure 12.2 Schematic for rebar deployment technique. Bent rebar is pounded into the stream bottom and the logger is attached to the rebar by cable, wire, or ziptie. The logger can also be attached to the rebar upright (not shown).

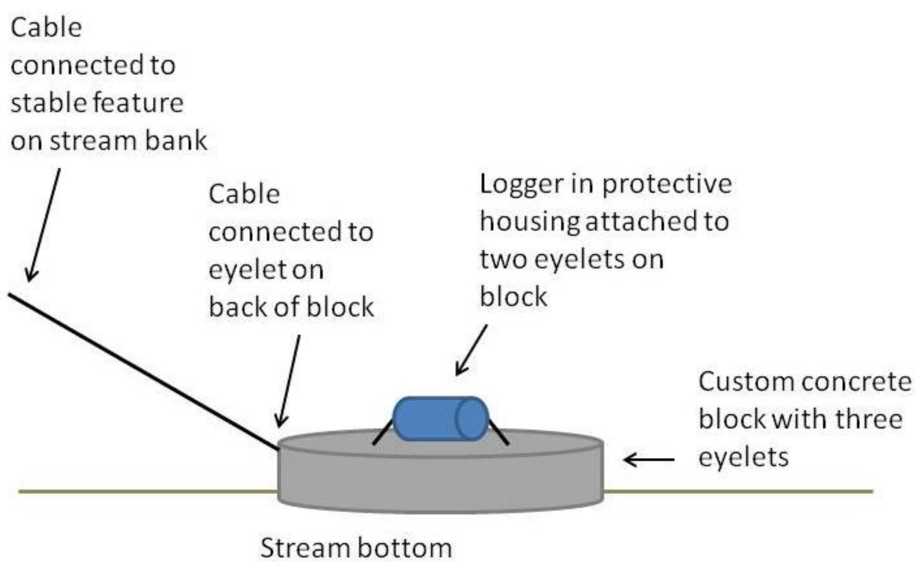

Figure 12.3 Schematic of the custom-built concrete block deployment technique. An eyelet on the block is attached to a stable feature on the stream bank with cable. The logger is connected to the block with cable, wire, or zipties at two eyelets on the block.

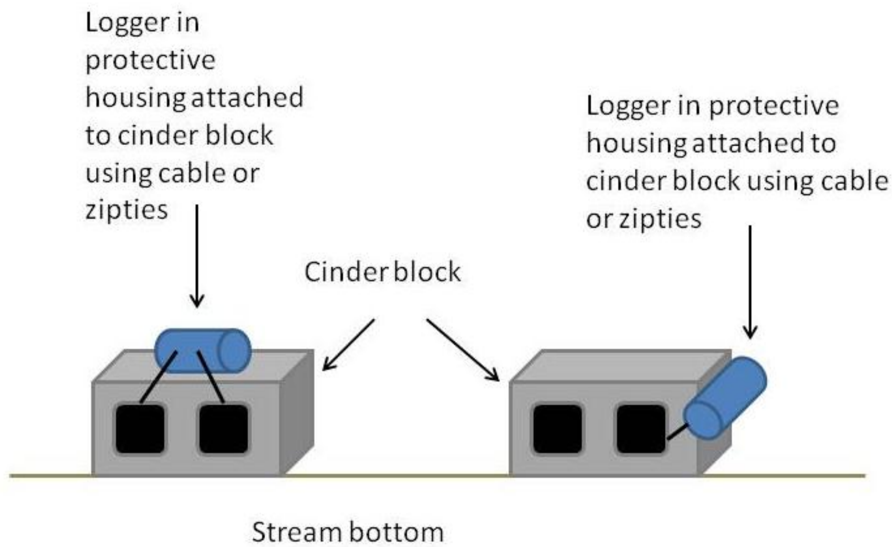

Figure 12.4 Schematic of cinder block deployment technique. The logger is attached to the cinder block using cable, wire, or zipties. The logger can be secured on the top or side of the cinder block. If secured on side of cinder block, the block should be oriented so that the logger is on the downstream side of the block. The cinder block can be secured to a stable structure on the stream bank for additional security. This is recommended for sites with periodic high flows.

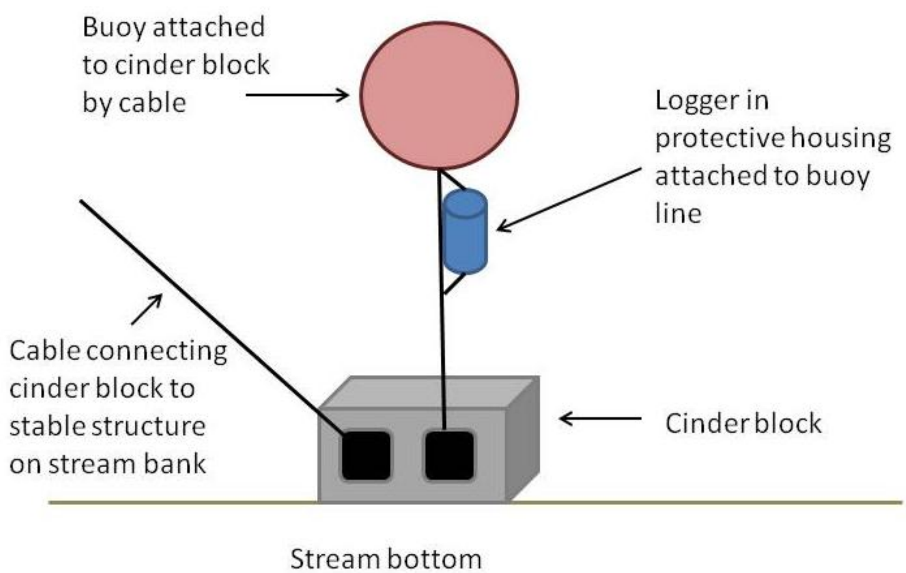

Figure 12.5 Schematic of weight and buoy deployment technique. A cinder block or other heavy item used as a weight is secured to a stable structure on the stream bank using a cable. A foam buoy is attached to the cinder block by cable (approximately 2-3 feet long). The logger is attached to the buoy line by cable, wire, or ziptie. Note that the buoy should not be floating on the surface of the water; rather, it should be below the water at all but the lowest flows.

Appendix E. Data Sheets for Lab and Field Accuracy Checks

Note that these data sheets should be filled in using Microsoft Excel in order to make use of the built-in calculation of error. Required calculations are listed on the data sheets in the event that data sheets are printed out and filled in by hand in the field.

Excel versions of these data sheets are saved here:

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Laboratory 2-Point Accuracy Check Data Sheet
Continuous Temperature Monitoring Program

Note: Shaded sections will be automatically calculated when data entered (in Excel)
Date
Serial Number of Logger
Serial Number of Reference Thermometer

Ice Water Bath

Time	Temperature Reading of Logger	Temperature Reading of Reference Thermometer	Difference in Temperature Readings
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
Average			0

Collect simultaneous readings of logger (set to record every 15 seconds) and reference thermometer (every minute). Calculate difference between reference thermometer reading and logger reading. Calculate average difference in temperature readings

Error at 0 degrees C

Room Temperature Bath

Time	Temperature Reading of Logger	Temperature Reading of Reference Thermometer	Difference in Temperature Readings
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
Average			0

Collect simultaneous readings of logger (set to record every 15 seconds) and reference thermometer (every minute). Calculate difference between reference thermometer reading and logger reading. Calculate average difference in temperature readings

Error at room temperature

Average of both temperatures	0

Average error

Does average difference in temperature readings exceed 0.2°C?

Logger deployment location (site number and description)

Figure 12.6 Laboratory Accuracy Check Data Sheet for use during two-point accuracy check prior to initial deployment of loggers and during annual laboratory check. This spreadsheet (when open in Excel) will automatically calculate areas in blue and gray.

Reference Probe Accuracy Check Data Sheet
Continuous Temperature Monitoring Program

Date ______________________________

Site Number ______________________________

Serial Number of Logger ______________________________

Calibration of field reference temperature probe

Time	Temperature Reading of Reference Probe	Temperature Reading of Reference Thermometer	Difference in Temperature Readings
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
Average			0

Does average difference in temperature readings exceed 0.2°C?

Figure 12.7 Field Accuracy Check Data Sheet for use in accuracy check of field reference temperature probe. This spreadsheet (when open in Excel) will automatically calculate areas in blue and gray.

Field Accuracy Check Data Sheet
Continuous Temperature Monitoring Program

Date	Site Number
Serial Number of Logger	
Previous Calibration Drift	

Total Error Calculation

Error of reference thermometer	0
Fouling error	#DIV/0!
Calibration drift	0
Total (Absolute) Error	#DIV/0!

Field Observations

Is the logger buried in sediment?	☐ Yes	☐ No
Is the logger dewatered?	☐ Yes	☐ No
Is the logger visibly fouled?	☐ Yes	☐ No
If fouled, describe fouling:		

Acceptance Criteria = ±0.5°C

☐ Meets acceptance criteria

☐ Does not meet acceptance criteria

Apply correction factors for:

☐ Error of reference thermometer - if checked, adjust column B

☐ Calibration drift error - if checked, adjust column C

☐ Additional data corrections needed - if checked, provide notes on potential corrections needed

A. Field temperature calibration check - Initial | **B. Adjusted data corrected for reference probe error** | **C. Adjusted data corrected for calibration drift**

Time	Temperature Reading of Logger	Temperature Reading of Reference Probe	Difference in Temperature Readings	B. Adjusted Temperature Reading of Reference Probe	B. Difference in Temperature Readings	C. Adjusted Temperature Reading of Logger	C. Difference in Temperature Readings
			0	0	0	0	0
			0	0	0	0	0
			0	0	0	0	0
			0	0	0	0	0
			0	0	0	0	0
			0	0	0	0	0
			0	0	0	0	0
			0	0	0	0	0
			0	0	0	0	0
			0	0	0	0	0
Net Calibration Drift			0		0		0

Field temperature calibration check - Fouling error and total calibration drift
****clean logger and note any fouling prior to this step****

Time	Temperature Reading of Logger	Temperature Reading of Reference Probe	Difference in Temperature Readings (calibration drift)	Adjusted Temperature Reading of Reference Probe	Difference in Temperature Readings (calibration drift)	Adjusted Temperature Reading of Logger	Difference in Temperature Readings (calibration drift)
			0	0	0	0	0
			0	0	0	0	0
			0	0	0	0	0
			0	0	0	0	0
			0	0	0	0	0
			0	0	0	0	0
			0	0	0	0	0
			0	0	0	0	0
			0	0	0	0	0
			0	0	0	0	0
Calibration Drift Error (diff in probe-logger)			0		0		0
Fouling Error (diff in temp pre- to post-cleaning)			#DIV/0!		#DIV/0!		0

Corrected Total Error Calculation	Ref probe error corrected	Calibration drift corrected
Error of reference thermometer	N/A	N/A
Fouling error	#DIV/0!	0
Calibration drift	0	0
Total (Absolute) Error	#DIV/0!	0

Figure 12.8 Field Accuracy Check Data Sheet for use during field accuracy checks and calculation of sensor error caused by fouling and sensor error caused by calibration drift. This spreadsheet (when open in Excel) will automatically calculate areas in blue and gray.

Field Accuracy Check Data Sheet
Continuous Temperature Monitoring Program

Date	Site Number
Serial Number of Logger	
Previous Calibration Drift	

Field Observations

Is the logger buried in sediment?	☐ Yes	☐ No
Is the logger dewatered?	☐ Yes	☐ No
Is the logger visibly fouled?	☐ Yes	☐ No
If fouled, describe fouling:		

Total Error Calculation

Error of reference thermometer	
Fouling error	
Calibration drift	
Total (Absolute) Error	

Acceptance Criteria = ±0.5°C

☐ Meets acceptance criteria

☐ Does not meet acceptance criteria

Apply correction factors for:

☐ Error of reference thermometer - if checked, adjust column B

☐ Calibration drift error - if checked, adjust column C

☐ Additional data corrections needed - if checked, provide notes on potential corrections needec

A. Field temperature calibration check - Initial

Time	Temperature Reading of Logger	Temperature Reading of Reference Probe	Difference in Temperature Readings
Net Calibration Drift			

B. Adjusted data - corrected for reference probe error

Adjusted Temperature Reading of Reference Probe	Difference in Temperature Readings

C. Adjusted data - corrected for calibration drift

Adjusted Temperature Reading of Logger	Difference in Temperature Readings

Field temperature calibration check - Fouling error and total calibration drift
****clean logger and note any fouling prior to this step****

Time	Temperature Reading of Logger	Temperature Reading of Reference Probe	Difference in Temperature Readings (calibration drift)	Adjusted Temperature Reading of Reference Probe	Difference in Temperature Readings (calibration drift)	Adjusted Temperature Reading of Logger	Difference in Temperature Readings (calibration drift)
Calibration Drift Error (diff in probe-logger)							
Fouling Error (diff in temp pre- to post-cleaning)							

Additional notes on back of this form

Corrected Total Error Calculation	Ref probe error corrected	Calibration drift corrected
Error of reference thermometer		
Fouling error		
Calibration drift		
Total (Absolute) Error		

Figure 12.9 Field Accuracy Check Data Sheet for use during field accuracy checks and calculation of sensor error caused by fouling and sensor error caused by calibration drift. This data sheet is for print only, and should only be used when access to Excel is not possible.

Cross-Section Survey Datasheet
Continuous Temperature Monitoring Program

Site ID
Description of cross-section location

Cross-section width	
Width of horizontal increments	
Number of horizontal increments	

Maximum depth	
Height of vertical increments	
Number of vertical increments	

Temperature readings (degrees C)		Horizontal increment number									
		1	2	3	4	5	6	7	8	9	10
		Distance from left bank									
Vertical Increment number	Depth from surface										
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											

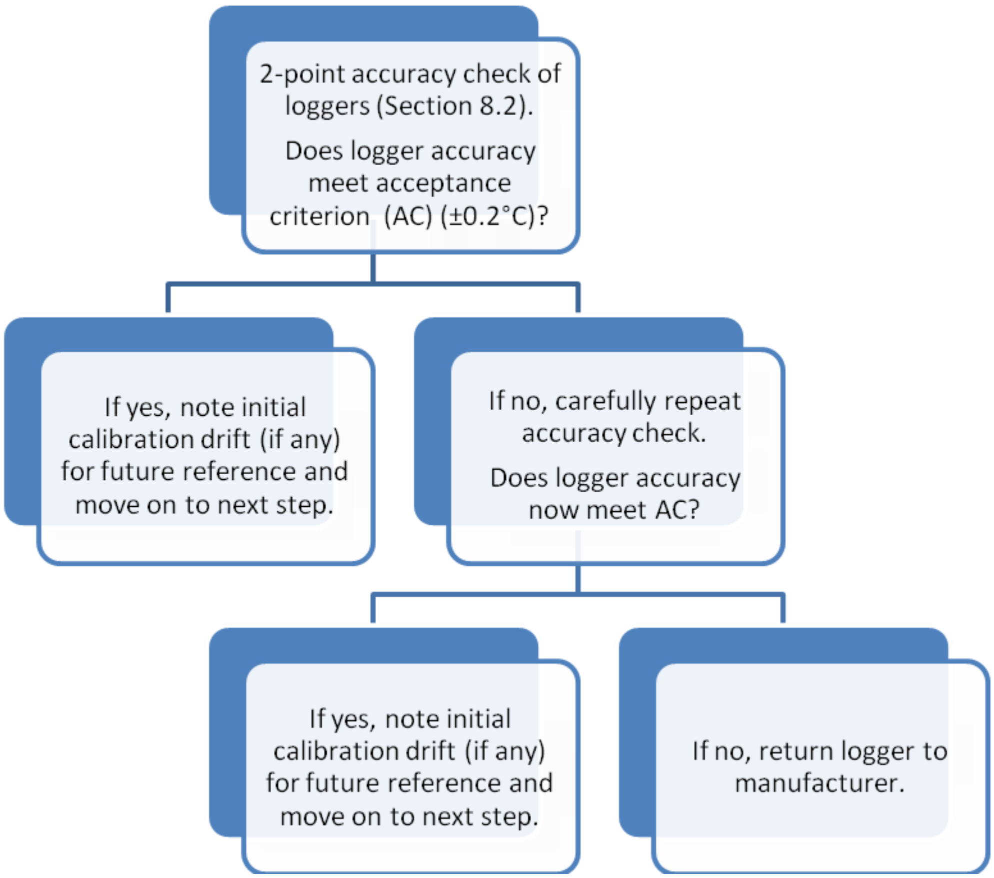
Mean temperature	#DIV/0!
Standard Deviation	#DIV/0!

Figure 12.10 Stream cross-section survey datasheet for use in determining representativeness of temperature logger deployment location and horizontal and vertical stratification.

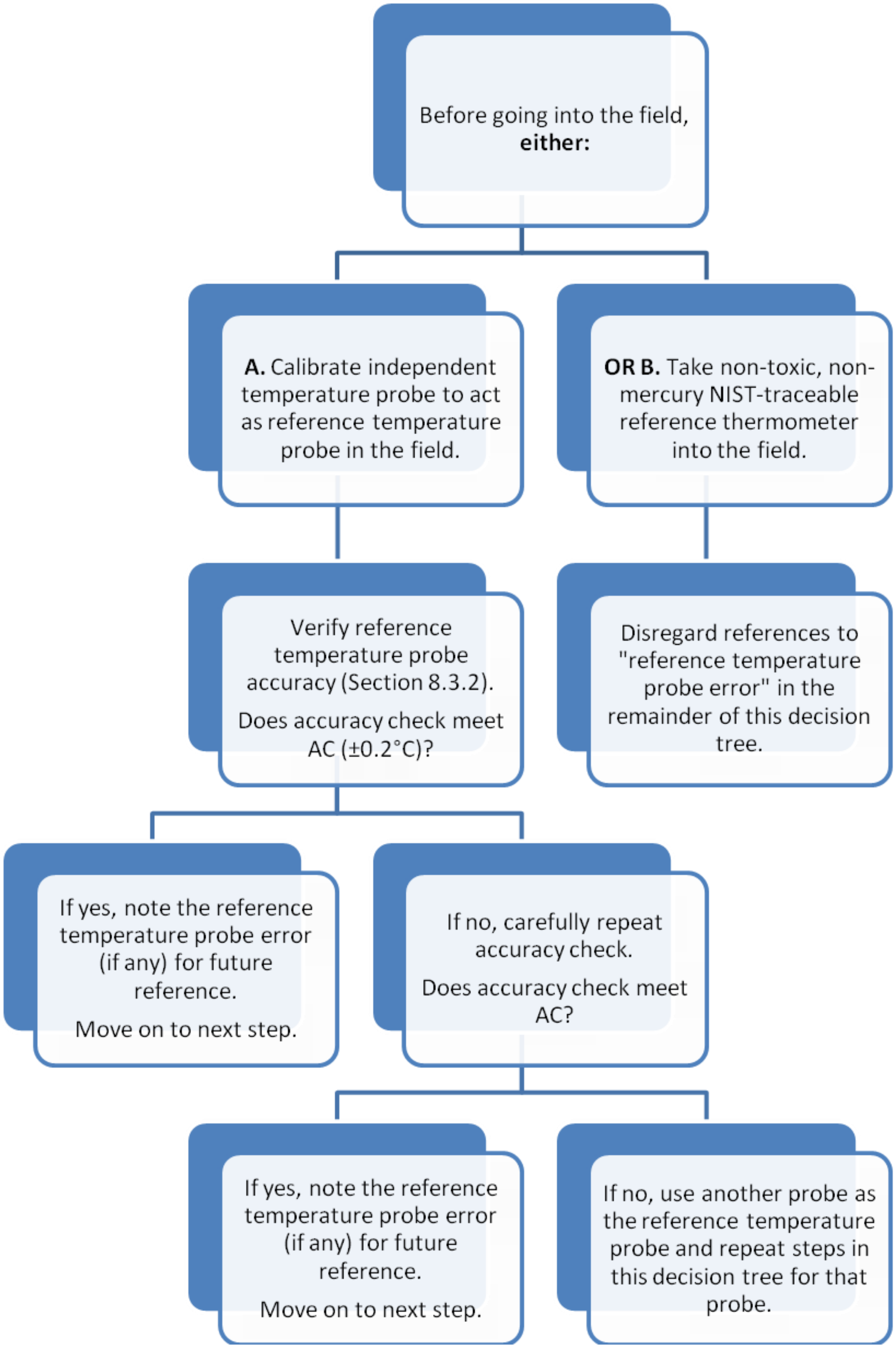
Appendix F. Decision Trees

This appendix includes decision trees for accuracy check prior to initial logger deployment in the field, preparation for quarterly field accuracy checks, conducting field accuracy checks (including calculation of total sensor error), and determining whether data corrections are needed.

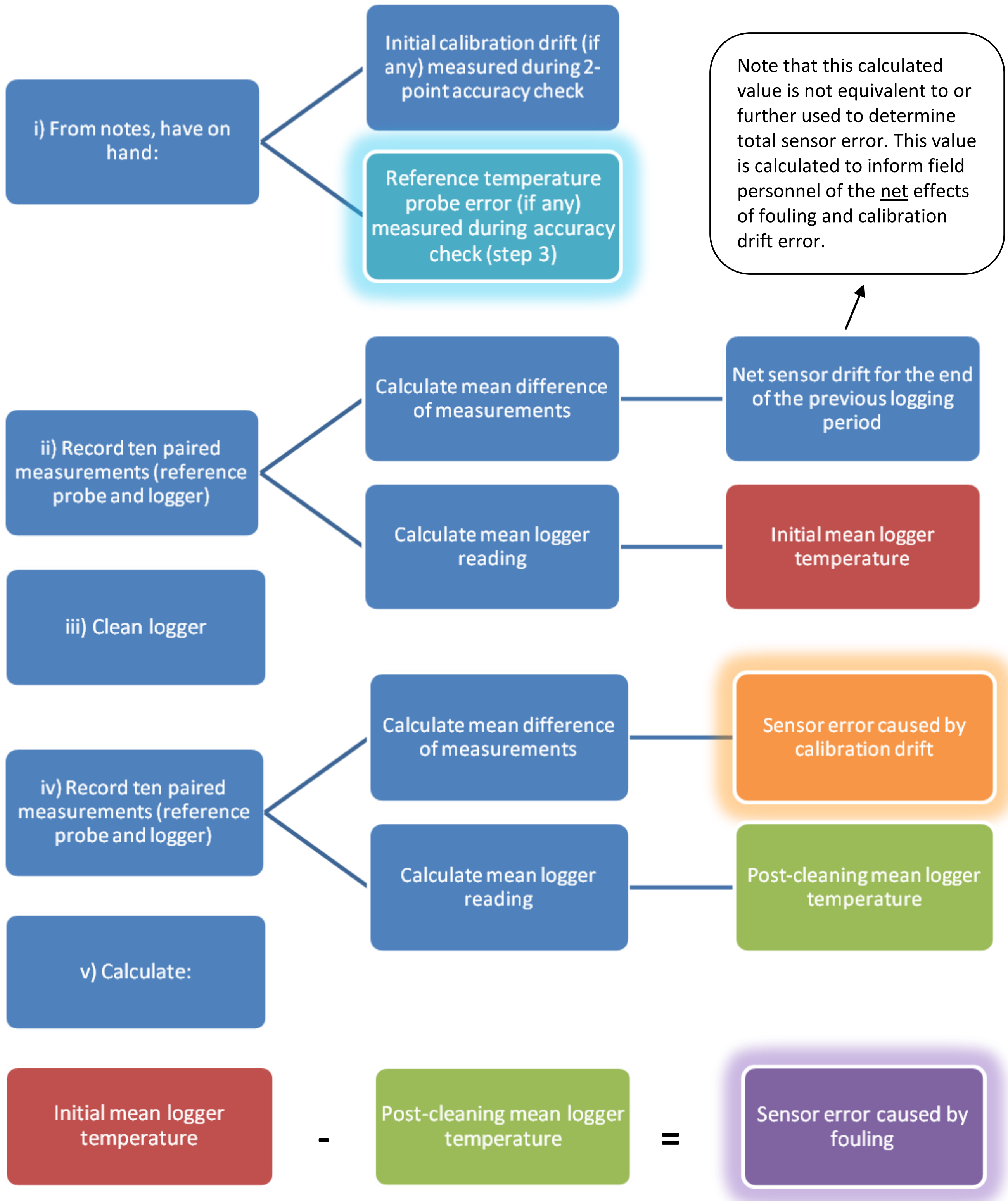
1) Accuracy check prior to initial logger deployment in the field:



2) Prepare for field QA/QC activities conducted on a quarterly basis (September, December, March, June):



3) In the field, conduct field accuracy check (Section 8.3.3):



4) Calculate total sensor error:

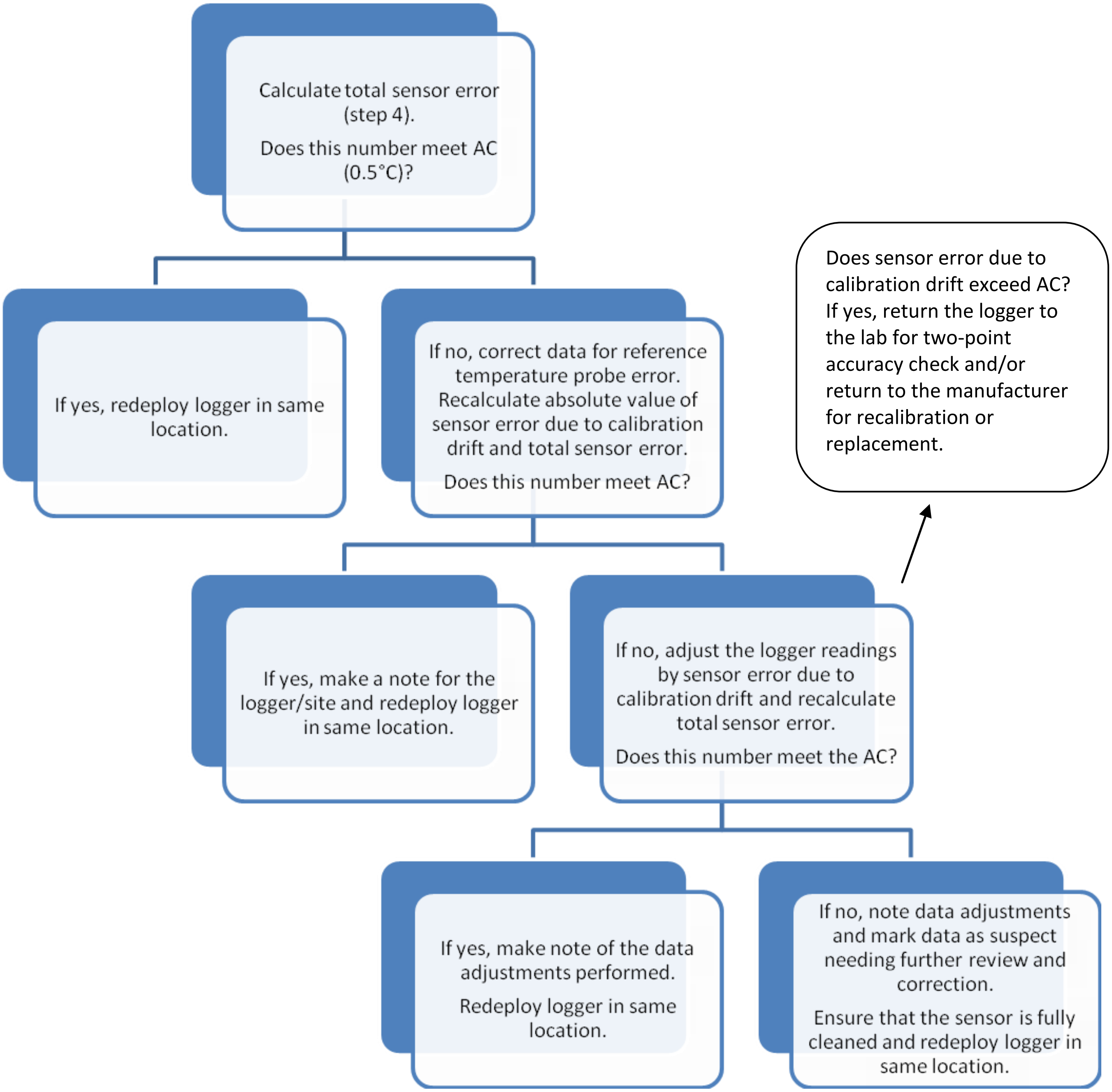
ABS[Reference temperature probe error]

ABS[Sensor error caused by calibration drift]

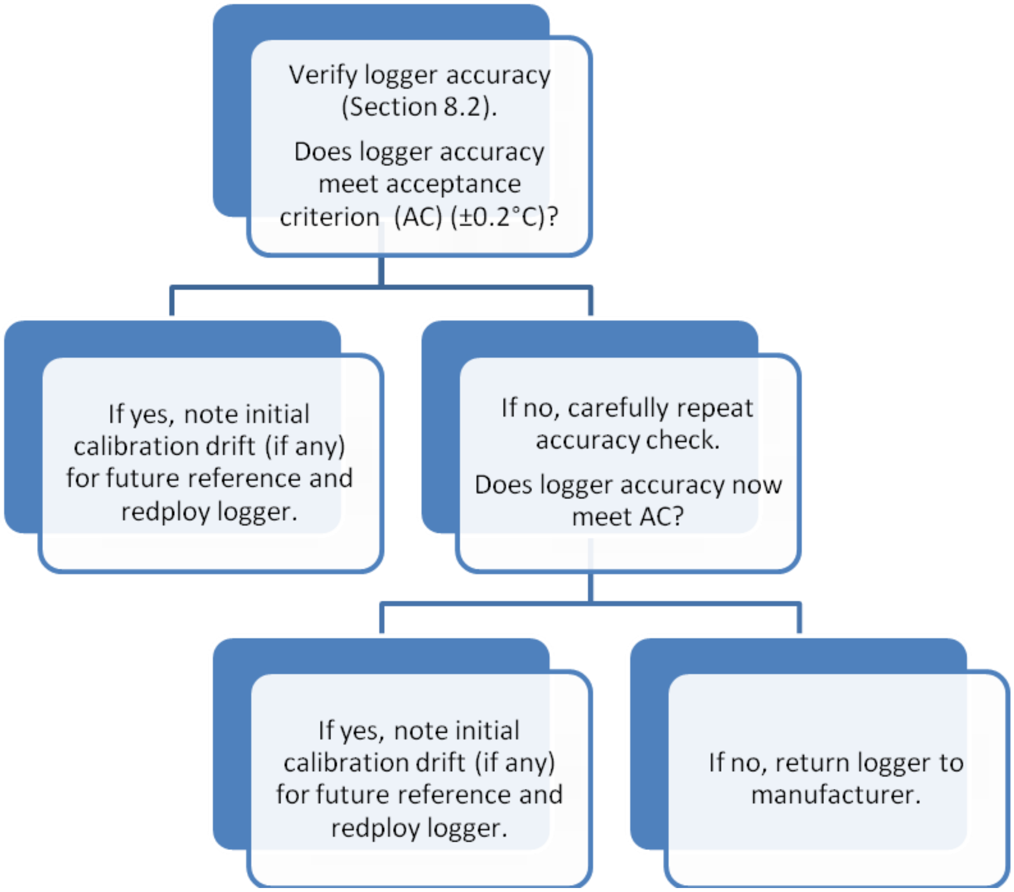
\+ ABS[Sensor error caused by fouling]

Total sensor error

5) Does total sensor error meet acceptance criterion (0.5°C) (Section 8.3.3)?

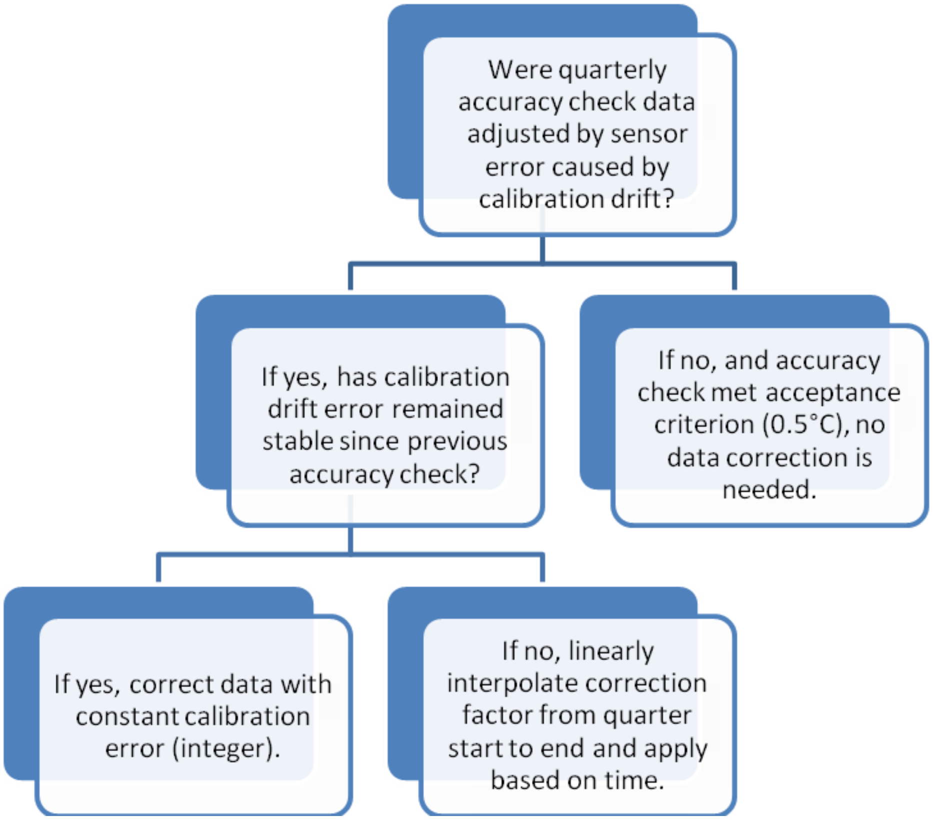


6) Annual lab QA/QC activities (September) (Section 8.4):



7) Decide whether data need to be corrected

a. Do you need to correct data for sensor error caused by calibration drift?



b. Do you need to correct for sensor error caused by fouling?